Cooperation in Climate Research: An Evaluation of the Activities Conducted Under the US-USSR Agreement for Environmental Protection Since 1974

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Climate Program Office

Dedicated to the memory of John A. Mirabito, the first Executive Coordinator of WG VIII. His efforts, dedication, and congenial personality established the environment so conducive to scientific collaboration that led to the growth and success of WG VIII.

Cooperation in Climate Research: An Evaluation of the Activities Conducted Under the US-USSR Agreement for Environmental Protection Since 1974

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To John -
Enjoy!
Renee

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TABLES AND FIGURES

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ACRONYMS

AGU . . . . . American Geophysical Union
ARL . . . . . Air Resources Laboratory (NOAA)

CAC . . . . . Climate Analysis Center
CAO . . . . . Central Aerological Observatory (Goskomgidromet)
CES . . . . . Committee on Earth Sciences

DOC . . . . . Department of Commerce
DOD . . . . . Department of Defense
DOE . . . . . Department of Energy
DOI . . . . . Department of Interior
DOS . . . . . Department of State

ECC . . . . . electrochemical concentration cell
ECE . . . . . Economic Commission for Europe
EPA . . . . . Environmental Protection Agency
ERB . . . . . earth radiation budget
ERBE . . . . . Earth Radiation Budget Experiment
ERL . . . . . Environmental Research Laboratories (NOAA)

GCM . . . . . general circulation model
GFDL . . . . . Geophysical Fluid Dynamics Laboratory (NOAA)
GISS . . . . . Goddard Institute for Space Studies (NASA)
GMCC . . . . . Geophysical Monitoring for Climatic Change (NOAA)
Goskompriroda . . State Committee for Protection of the Natural Environment
Goskomgidromet. . State Committee for Hydrometeorology

HAO . . . . . High Altitude Observatory (NCAR)
HIP . . . . . Heiss Island Project

IAMAP . . . . . International Association for Meteorology and Atmospheric Physics
ICSU . . . . . International Council of Scientific Unions
IGBP . . . . . International Geosphere-Biosphere Program
INQUA . . . . . International Union for Quaternary Research
IOC . . . . . International Oceanographic Commission
IPCC . . . . . Intergovernmental Panel on Climate Change
ISCCP . . . . . International Satellite Cloud Climatology Project
ITCZ . . . . . Intertropical Convergence Zone

JCM . . . . . Joint Committee Meeting

LLNL . . . . . Lawrence Livermore National Laboratory (DOE)

MGO . . . . . Main Geophysical Observatory (Goskomgidromet)

NAS . . . . . National Academy of Sciences
NASA . . . . . National Aeronautics & Space Administration
NCAR . . . . . National Center for Atmospheric Research
NCDC . . . . . National Climate Data Center
NCP . . . . . National Climate Program
NCPO . . . . . National Climate Program Office
NOAA . . . . . National Oceanic & Atmospheric Administration
NRC . . . . . National Research Council
NRL . . . . . Naval Research Laboratory
NSF . . . . . National Science Foundation

OECD . . . . . Organization for Economic Cooperation & Development
OSTP . . . . . Office of Science and Technology Policy
OSU . . . . . Oregon State University

PMEL . . . . . Pacific Marine Environmental Laboratory (NOAA)
PSC . . . . . polar stratospheric cloud

SAGA . . . . . Soviet-American Gas Aerosol (expedition)
SHI . . . . . State Hydrological Institute (Goskomgidromet)
SIO . . . . . Scripps Institute of Oceanography

TOMS . . . . . Total Ozone Mapping Spectrometer

UNEP . . . . . United Nations Environmental Program
US . . . . . United States
USSR . . . . . Union of Soviet Socialist Republics

WCP . . . . . World Climate Programme
WCRP . . . . . World Climate Research Programme
WMO . . . . . World Meteorological Organization

Chapter 1

INTRODUCTION

On May 23, 1972, the US and USSR established a joint Agreement on Protection of the Environment. This agreement was the first of its kind between the US and USSR on environmental issues, which today are at the center of intense international concern. The agreement promotes joint cooperation in 11 areas of study, ranging from pollution of the air, water, and agriculture to legal protection measures (Table 1.1).

Research on climate change and atmospheric chemistry is conducted under Working Group VIII (WG VIII). The goals of WG VIII are to foster cooperative projects between the US and USSR that will improve our common understanding of the Earth's climate and its sensitivity to natural and anthropogenic environmental changes. Since its inception in June 1974, the organization and activities of WG VIII have evolved to reflect the growing awareness of potential environmental problems created by greenhouse gases, chlorofluorocarbon (CFC)-induced ozone depletion, and their combined effects on the global climate system.

This report discusses the historical development of WG VIII since 1974. It presents the background of the US-USSR Agreement for Environmental Protection as well as WG VIII's organization. Major scientific achievements within the program are evaluated, and factors contributing to WG VIII's effectiveness and limitations are identified as well. Finally, WG VIII's prospects for the future are analyzed, including its benefit to science in general, its ability to act as a good role model for other collaborative efforts, and recommendations for increased effectiveness in the program.

This report is based, in part, on a survey of some of the US scientists (Appendix A) who have participated in the scientific exchanges since 1974. Surveys were sent to 111 participants. Of the 87 participants who responded, 44 were actually involved in joint experiments, climate modeling efforts, and instrument/technique comparisons and intercalibrations (Appendix B). The responses of these US participants were particularly useful for providing highlights of WG VIII's scientific achievements as well as identifying deficient areas. Consequently, many of the concluding recommendations presented in this report reflect the comments of these scientists. This survey was not intended to provide a scientific or statistical evaluation. Rather, the information gathered was used to illuminate additional facets of issues presented throughout this report.

TABLE 1.1

AREAS SELECTED FOR STUDY UNDER THE
US-USSR AGREEMENT ON PROTECTION OF THE ENVIRONMENT

Areas	Subject
I	Prevention of Air Pollution
II	Prevention of Pollution Effects on Vegetation -- Including Forest Ecosystems
III	Prevention of Pollution Associated With Agricultural Production
IV	Enhancement of the Urban Environment
V	Protection of Nature and the Organization of Preserves
VI	Protection of the Marine Environment From Pollution
VII	Biological and Genetic Effects of Environmental Pollution
VIII	***INFLUENCE OF ENVIRONMENTAL CHANGES ON CLIMATE***
IX	Earthquake Prediction
X	Arctic and Subarctic Ecological Systems
XI	Legal and Administrative Measures for Protecting Environmental Quality
XII	Information, Education, and Training in the Field of Environmental Protection (proposed)

Source: Memorandum of the Twelfth Meeting of the US-USSR Joint Committee Meeting on Cooperation in the Field of Environmental Protection, Washington, D.C., January 9-12, 1990.

In addition, access to complete files, cables, field trip reports, WG VIII protocols, and personal interviews provided supplementary details on the historical development of WG VIII. In particular, for their earlier overview of WG VIII up to 1981, the author is indebted to Eugene Bierly and to John Mirabito, the first Executive Secretary of WG VIII and to whom this report is dedicated.[1]

An analysis of the activities of WG VIII reveals that both the US and USSR have derived advantages from the joint research within WG VIII. It has brought together a team of scientists

[1]Eugene W. Bierly and John A. Mirabito, "The U.S.-U.S.S.R. Agreement on Protection of the Environment and its Relationship to the U.S. National Climate Program," Bulletin of the American Meteorological Society 65 (January 1984): 11-19.

that is capable of making significant contributions to a better understanding in the political as well as scientific communities regarding anthropogenic influences on our global climate system.

Chapter 2

BACKGROUND AND IMPLEMENTATION OF WORKING GROUP VIII

The first meeting of the US-USSR Joint Committee on Cooperation in the Field of Environmental Protection was held in Moscow, September 18-21, 1972. The Joint Committee (JC) meets once a year, alternately in Moscow and Washington, D.C. However, the JC did not meet from 1979 to 1985 because of US sanctions against the USSR following their incursion into Afghanistan. President Reagan re-established the JC on November 12-19, 1985, with a renewal of its commitment to continue cooperation on the basis of equality, reciprocity, and mutual benefit as mandated in the 1972 agreement between President Richard M. Nixon and President Nicolai V. Podgorny.

On the US side, the agreement is directed by the Administrator of the Environmental Protection Agency (EPA). On the USSR side, responsibility for directing all international activities has been, until recently, with the State Committee for Hydrometeorology and the Protection of the Environment (Goskomgidromet). However, in February 1988, the State Committee for Protection of the Natural Environment (Goskompriroda) was created, and was subsequently given the responsibility for implementing the environmental agreement. Within the EPA, a secretariat was established to coordinate U.S. activities in the 11 areas under the agreement. The head of the secretariat serves as the Executive Secretary to the U.S. Co-Chairman. The secretariat in the Soviet Union is located in Moscow at the main administration of Goskompriroda. Appendix C is a list of the Joint Committee Chairmen and Executive Secretaries since the agreement's inception in 1972.

2.1 ORGANIZATION OF WG VIII

It was decided at the first JCM in 1972 that the group dealing with the influence of environmental changes on climate would be identified as Working Group VIII (WG VIII). The National Oceanic and Atmospheric Administration (NOAA) was designated as lead agency to coordinate US participation in WG VIII. The Hydrometeorological Service (subsequently changed in 1978 to Goskomgidromet) was designated as lead agency for WG VIII in the Soviet Union. Today, implementation of the various WG VIII projects is coordinated within the US by the National Climate Program Office (NOAA/NCPO) and within the USSR by the State Committee for Hydrometeorology (Goskomgidromet).

Working Group VIII activities include visits to laboratories, universities, observatories, computer centers, field sites and other appropriate institutions; meetings, symposia, and workshops dealing with specific climate-related topics; joint experiments (shipborne, air, and land based); joint publications; exchanges of data; and comparison of measurement techniques and instruments.

All activities are conducted on a "receiving side pays" basis. In other words, the host country is responsible for lodging and travel from point of entry to point of departure. A per diem is also provided by the host country to cover subsistence and incidental expenses.[2] In addition, the Soviet Union provides free medical care for visiting US scientists, and health insurance is provided for visiting Soviet scientists by Blue Cross/Blue Shield (administered through NOAA).

The first full meeting of WG VIII was held in Leningrad, June 10-21, 1974; subsequent annual meetings have been alternately held in the US and the USSR. Appendices D and E provide a complete summary of WG VIII co-chairmen, coordinators, and project leaders since 1974. Over its 15-year history, the central administration of WG VIII has remained in the hands of relatively few individuals. This has provided a strong element of continuity in the activities within the program and has contributed to its overall success.

Although WG VIII represents a commitment of US and USSR resources, appropriation of funds for US participation in the program has not been included as a line item in either EPA's or NOAA's budget. Those federal agencies wishing to take part in WG VIII activities do so by allocating resources from other scientifically related programs. The predominant agencies which have participated in WG VIII include NOAA, NASA, EPA, USGS, and DOE. Interested university scientists are generally supported by National Science Foundation (NSF) grants. However, there is no stable level of fiscal support to insure continued participation of interested competent scientists associated with the US-USSR bilateral activities. Problems associated with this manner of funding will be discussed in another chapter of this report. There are also a few instances in which participants have come from the private sector, but federal agencies and universities predominate.

In general, US participation in WG VIII activities has been evenly divided between the university sector and federal

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[2]Current per diem rates are $21 in the US and 14 rubles in the USSR.

agencies. On the USSR side, scientists come from the many institutes connected with Goskomgidromet or the Academy of Sciences of the USSR. Both Leningrad and Moscow State Universities have also been represented. Appendix F lists US and USSR institutions which have participated in the WG VIII program (not including annual meetings).

2.2 FOCUS OF PROJECTS

Working Group VIII was initially organized into three major projects having five centers of activity. The projects were organized as follows:

PROJECT 02.08-11: *Effects of changes in the heat balance of the atmosphere on climate*

1) *Modeling and documentation of past climate*
2) *Modeling and diagnosis of present climate*
3) *Polar and oceanic influence on climate*

PROJECT 02.08-12: *Effects of pollution of the atmosphere on climate*

4) *Study and documentation of trace gases and aerosols and their impact on climate*

PROJECT 02.08-13: *Influence of changes in solar activity on climate*

5) *Study and documentation of physical processes that govern the potential interaction between climate and the sun and earth*

Effects of Changes in Heat Balance

The predominant emphasis in this project (Project 11) was on paleoclimate reconstruction and model development, with very little activity centered on polar and oceanic influences on climate. Efforts began in 1976 to look at past climates as possible analogs for future climates because it was thought that information on long-range climatological trends could be used to make preliminary forecasts of future climates. These efforts culminated in a 1983 three-volume joint compilation of paleoclimate data for the Pleistocene in the US and USSR, Late Quaternary Environments of the United States and the Soviet Union. The two American volumes were selected by Choice magazine to be among their Outstanding Academic Books of 1984. Choice magazine is the influential journal, published by the Association of College and Research Libraries, which reviews virtually all published books for library acquisition. The Soviet volume was

timely in light of efforts to use paleoclimate data to test results simulated by general circulation models (GCMs) and included some innovative and useful techniques by USSR scientists as well as some ambitious reconstructions.[3] Overall, the US and USSR volumes represented a unique contribution to the field of paleoclimate studies since this facilitated a more comprehensive consideration of the influence of atmosphere, ocean, and atmosphere-land systems on the evolution of the environment in most of the Northern Hemisphere during the late Pleistocene and Holocene periods.

Conferences on climates of the Pleistocene and Holocene epochs were also held every other year beginning in 1976, to discuss various aspects of US and USSR research on these periods. The last conference in 1982 was convened to coincide with the XI Congress of the International Union for Quaternary Research (INQUA), where results of US and USSR joint research were presented in the paleogeography section and in a special symposium on "Changes of Climate in the Late Cenozoic and its Prediction."

Modeling and diagnosis of present climate also became active in 1975. US and USSR scientists focused on the development of simple and complex models which have been used to assess the role of physical processes in climate formation and its possible natural changes and variations caused by anthropogenic factors. Further details on the evolution of research in climate modeling will be presented in another section of this report.

Unfortunately, joint research on the interactions of the atmosphere with polar regions and the oceans never fully developed. There were two exchanges in 1976 at the University of Washington (Seattle) and the Arctic and Antarctic Institute (Leningrad), which provided the first opportunities for US and USSR scientists to review results of US arctic work and to learn about Soviet activities in the field. In addition, samples of ice cores from US and Soviet sites in Antarctica were exchanged in 1976 for comparison and study. The last activity in this area occurred in 1977 when three Soviet scientists visited the University of Washington to discuss the exchange of snow and ice data and to propose research of the air-sea exchange in ice-free waters of the polar regions.

Within the last few years, however, General Secretary Gorbachev has indicated an increased interest in Arctic science,

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[3] The Quarterly Review of Biology 60 (September 1985): 387.

in general,[4] and more activities within WG VIII have been created to take advantage of this renewed opportunity for climate-related research in this region. These activities will be discussed later.

Project 11 took on a new focus in 1978 in response to concern that increasing levels of carbon dioxide could significantly affect future climate conditions. A series of meetings, symposia, and workshops took place in Tashkent (1976), Leningrad (1977), Dushanbe (1978) and Tbilisi (1979) to discuss basic questions about the trend of the atmosphere's temperature, data bases being used, and interpretation of climate modeling results. The results of these discussions were of considerable scientific interest and served to inform scientists on the climate-related activities being conducted in the US and USSR.

In particular, the 1978 symposium on the effects of changes in atmospheric carbon dioxide in Dushanbe recommended that US/USSR collaborative efforts be directed toward the following main problems:[5]

(1) Assessment of carbon dioxide variations based on the study of natural and anthropogenic contributions to the global carbon dioxide balance;

(2) Computation of climate change resulting from a growth in concentrations of atmospheric carbon dioxide by using various climate models; and

(3) Evaluation of the effects of climate change and atmospheric chemical composition on various environmental components and on man's economic activities, including agriculture.

At a 1981 workshop in Leningrad on atmospheric carbon dioxide and climate, US and USSR scientists agreed for the first

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[4]John B. Hannigan and Milada Selucka, "Recent Developments in Environmental and Science Policy in the Soviet Union and the Impact on the Soviet North," a report prepared for the Circumpolar and Scientific Affairs Directorate of the Department of Indian Affairs and Northern Development, Ottawa, Canada, March 15, 1989. Conclusions provided to the author by the National Science Foundation.

[5]Eugene W. Bierly, Mikhail I. Budyko, et al., "Report of the US/USSR Workshop on the Climatic Effects of Increased Atmospheric Carbon Dioxide," June 15-20, 1981, prepared by the National Climate Program Office, Rockville, MD.

time on the qualitative aspects of such an important problem, even though there was disagreement on the quantitative aspects. The workshop, which established an effective scientific framework for future exchanges on the CO_2-climate relationship, concluded that:

(1) The effects of anthropogenic activities on the atmosphere are increasing at a rate that makes their significant influence on global climate more and more certain. This is especially true of the rising level of CO_2 in the atmosphere as a result of fossil fuel combustion;

(2) The best available climate models indicate that the principal climatic consequence of this CO_2 increase may be an overall global warming of a few degrees centigrade by the end of the 21st century. Such warming could occur as early as 2030 to 2060;

(3) The best available estimates from models and empirical studies further suggest that the greatest warming is likely to occur in higher latitudes, particularly in the Northern Hemisphere; and

(4) Such warming and associated changes of precipitation and other climatic elements may have important consequences on the biosphere and on agricultural and other economic activities of mankind.[6]

Furthermore, it was concluded that US/USSR cooperation in climate research was crucial and should be continued and strengthened because of the long-term significance that this issue could have for the economies of both countries.

Atmospheric Aerosols

The initial emphasis in this project (Project 12) was on evaluating the composition of atmospheric aerosols which could affect climate change. Subsequently, a cooperative program in precipitation chemistry was implemented and continues to this date. This program has involved the exchanges of specific laboratory methods and equipment, samples for comparison of analyses, and appropriate US and USSR specialists. In addition, the first successful joint experiment on stratospheric aerosols was conducted in mid-1975 involving balloon, aircraft, and ground-based measurements using US and USSR instruments. More

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[6]Ibid.

information on this experiment is provided in another section of this report.

However, as early as 1976, this project began to focus on pressing environmental problems, and emphasis for additional research was broadened to include investigation of the spatial concentration, composition and other properties of ozone, carbon dioxide, and other radiatively active atmospheric constituents. Consequently, exchanges were conducted to assess the effects of chlorofluorocarbons on stratospheric ozone, compare and calibrate US and USSR instruments used to measure ozone and turbidity, and study methods for CO_2 measurement and analysis.

In 1977, data on the production and use of chlorofluorocarbons in the USSR were presented to the US delegation during the third annual meeting of WG VIII. This was the first information the US received on USSR production of CFCs. More recently, but not within the framework of WG VIII, the USSR provided their 1986 production figures in a public forum in Leesburg, Virginia, and on a confidential basis to UNEP in 1988. In addition, under the Montreal Protocol, ratified in January 1989, CFC production information is to be provided on an annual basis to the UNEP Secretariat.[7]

It is interesting to note that WG VIII was at the cutting edge of research conducted in this area. A telegram in 1980 from the U.S. Department of State to Chairman Yuriy Izrael, Goskomgidromet, for the first time indicated concern over prospective damage to the stratospheric ozone layer as a result of increasing concentrations of CFCs and pointed to the need for further joint activities. Furthermore, the U.S. was not willing to adopt a "wait-and-see policy" but prepared to push ahead to study the effects on the ozone layer as a result of CFC "misuse."[8] Subsequently, WG VIII played a crucial role in preparing Soviet scientists for participation in international negotiations leading in 1987 to the Montreal Protocol which limits CFC emissions.[9]

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[7]Information was provided to the author by Steve Seidel, Environmental Protection Agency, July 28, 1989.

[8]Telegram from Department of State to Chairman Yuriy Izrael, USSR State Committee for Hydrometeorology and Control of the Natural Environment, August 22, 1980.

[9]The US and USSR both ratified this protocol on April 21, 1988, and November 10, 1988, respectively.

Chapter 2

Solar Changes and Climate

Early investigation under this project (Project 13) included research on the correlation of solar and climate effects, experimental and theoretical studies of changes in the solar constant and spectral solar radiation, numerical modeling of atmospheric responses to photochemical changes, electrical field measurements at high altitude stations, and the possible role of solar-terrestrial factors. Work in this area was largely focused on correlation of solar and climate events.

In 1981 more emphasis was placed on assessing the physical basis of solar-climate links, continued modeling of atmospheric responses to variable solar radiation, and the study of possible connections between solar variability and climate using tree-ring data. While the US placed considerable emphasis on the use of tree-ring data in climate studies, access to and exchange of USSR tree-ring data was minimal. Much of the USSR data received by US scientists is summarized in Paleoclimate Analysis and Modeling.[10]

Restructuring WG VIII

In 1986, WG VIII was significantly changed as the result of a number of related activities. First, increased emphasis was placed on the issue of global climate change. A major international conference to discuss global climate change was held October 1985 in Villach, Austria. This conference, sponsored by WMO, UNEP, and ICSU, brought together scientists from 29 industrialized and developing countries. The scientists concluded that greenhouse gases were expected to cause a significant warming of the global climate and that these gases were increasing as a result of human activity.[11] The subsequent appointment of Mikhail Budyko, a leading Soviet climatologist, as USSR Co-Chairman of WG VIII in 1986 resulted in considerable emphasis being placed within the program on greenhouse climate change and projections of future climate. In addition, in

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[10]C. W. Stockton, W. R. Boggess, and D. M. Meko, "Climate and Tree Rings," in Paleoclimate Analysis and Modeling, ed. A. D. Hecht (New York: John Wiley and Sons, 1985): 71-151.

[11]World Climate Programme, Developing Policies for Responding to Climatic Change, a summary of the discussions and recommendations of the workshops held in Villach (28 September-2 October 1987) and Bellagio (9-13 November 1987), under the auspices of the Beijer Institute, Stockholm, WMO/TD-No. 225 (April 1988), World Meteorological Organization, Geneva.

response to recommendations of the conference for a start on policy analysis to identify the widest possible range of social and economic responses for limiting or adapting to climatic changes, a new subproject on "climate impact assessment" was proposed. Activities in this area have been slow to develop but are now being considered as part of Working Group VII.

Second, a re-evaluation of activities resulted in the elimination of some that were considered less productive, i.e., solar-climate studies, and the expansion of others such as cloud climatology, modeling of cloud-radiation feedbacks, and cooperative ozone studies. Third, the increased activities resulted in a long-term plan for data exchange. As a result, a new project for data management was created as a result of the growth and importance of data exchanges which complemented the other existing projects.

In 1989, WG VIII again considered certain organizational problems regarding its structure. In particular, the growing scope and importance of ozone layer depletion mandated a separate project to study this problem (it had previously been included under the project for atmospheric aerosols). Subsequently, the scope of the projects was redefined as follows:

PROJECT 02.08-11: *Climate change*
- *a) Assessment of climate change*
- *b) Paleoclimate studies*
- *c) Consequences of climate change*

PROJECT 02.08-12: *Atmospheric composition*

PROJECT 02.08-13: *Radiative fluxes, cloud climatology, and climate modeling*

PROJECT 02.08-14: *Data exchange management*

PROJECT 02.08-15: *Stratospheric ozone*

WG VIII activities were given further impetus in 1987 when President Reagan and General Secretary Gorbachev signed a joint communique emphasizing the global environmental issue. In particular, a special report, Prospects for Future Climate: A Special U.S./U.S.S.R. Report on Climate and Climate Change, was initiated which will be published both in the US and in the USSR during 1990.

As a result of these changes, increased emphasis on greenhouse climate change was developed in Project 11. The

development of climate-change research and associated impacts, however, has not kept pace even though research conducted in WG VIII and in other programs indicates that the potential magnitude and rate of climate change poses serious environmental, social, and economic consequences. This is a crucial issue, and the subject was shifted to Working Group VII, as indicated previously, but to date there has been no action.

Paleoclimate studies began to take on renewed importance as the question of using past warm intervals as an analog for future climates was again raised by Soviet scientists. In particular, aside from the conferences previously discussed and a small meeting in 1987, the main contact more recently was a US-USSR Workshop on Paleoclimate Reconstruction and Modeling held at the University of Wisconsin in Madison in September 1988. The workshop was particularly noteworthy because most of the Soviet delegation were young, active scientists making their first trip to the United States (Figure 2.1). Project 11's first joint study was also recently conducted in July and August 1989 in the far eastern Soviet Union; lake core samples were collected for further paleoclimatic research.

Activities in Project 12 continue to center on monitoring those parts of the atmosphere that affect the Earth's heat budget, i.e., trace gases and aerosols. Such studies are conducted not only from land-based stations but also aboard specially equipped research vessels. They are augmented by joint calibration of US and Soviet instruments, i.e., Dobson spectrophotometers, which are used to ensure the continuation of compatible long-term observations of ozone distribution. Significant joint cruises and experiments have been organized under this project and will be discussed in greater detail in the next section. The 1975 Rylsk experiment was the first large-scale land-based project, but others include a 1989 experiment at Heiss Island in the Soviet Arctic to detect stratospheric ozone depletion and one in Central Asia on desert aerosols.

The scope of activities within Project 13 was changed following elimination of sun-weather-climate studies. It was clear that radiation flux and cloud processes play a crucial role in the greenhouse effect. Subsequently, in 1988 both sides considered the long-term prospects for cooperative studies of radiation processes in climate, and it was agreed that Project 13 should focus on investigation of radiative properties of clouds, ascertaining the present state of networks measuring solar radiation, and conducting satellite measurements of the earth's radiation budget (ERB).

Figure 2.1. Attendees at the US-USSR Workshop on Paleoclimate Reconstruction and Modeling, University of Wisconsin-Madison, 13-15 September, 1988. Front row: Herb Wright, Jr., University of Minnesota; Robert Etkins, NCPO; William Curry, NSF; Alan Hecht, NCPO; Andrei Velichko, Institute of Geography of the USSR Academy of Sciences, Moscow; John Kutzbach, University of Wisconsin-Madison; Alayne Street-Perrott, Oxford University, England; Melanie Woodworth, University of Wisconsin-Madison. Back row: Tom Webb III, Brown University; Michael MacCracken, Lawrence Livermore National Laboratory; Olga Borisova, Institute of Geography of the USSR Academy of Sciences; Irina Borzenkova, State Hydrological Institute, Leningrad; Patrick Bartlein, University of Oregon; Marjorie Winkler, University of Wisconsin-Madison; Robert Thompson, US Geological Survey; Brian Huntley, University of Durham, England; Vladimir Nechaev, Institute of Geography, USSR AS; Vladimir Klimanov, Institute of Geography, USSR AS. Not shown: Victor Mazo, Institute of Geography, USSR AS.

Satellite cloud data from both countries are given to the International Satellite Cloud Climatology Project (ISCCP), which was established in 1983 by the World Climate Research Programme (WCRP). ISCCP provides validation of the operational climatology component through more detailed field experiments and modeling

studies, works to improve satellite analysis techniques, and translates these combined results into improved climate model treatments of cloud-radiation processes.

In addition, cooperative activities within this project will be used to promote the US-sponsored Earth Radiation Budget Experiment (ERBE), which was launched in 1984 to derive global distributions of: (1) cloud-radiative forcing, which describes the effect of clouds upon the radiation energy balance of the earth, and (2) the clear-sky radiative heating of the planet, which is one of the forcing terms governing climate change. Satellite measurements from Nimbus-6 and -7 provide a powerful data set for use in climate diagnostic studies and climate model validation and improvement. It is anticipated that a similar joint USSR/France experiment (SCARABE), which uses the USSR "Meteor" satellite system, will join the activities coordinated within ERBE in 1990 and will include: satellite calibration procedures, data formats, retrieval algorithms, and opportunities for simultaneous observations.

The project on data management (and related analysis), Project 14, was established in 1986 to develop global archives of climatologically arrayed data. Project scientists continue to assess the state of oceanographic data archives in both countries as well as monitor the exchange of climatological data. These exchanges use existing channels which compile special catalogs of climate data, namely, the two larger World Data Centers in Asheville, North Carolina, and in Moscow. Further information on the activities conducted within this project will be discussed in another section of this chapter.

Project 15, the newest addition to the program, is designed to allow greater flexibility in meeting the needs of research in natural and anthropogenic changes in the ozone layer. Research in this area was originally under Project 12. However, with the increased attention on stratospheric ozone depletion and its role in climate change, the US and USSR agreed that a separate project was warranted. Emphasis in this project will continue with the ozone-depletion studies in both the Antarctic and Arctic regions. Scientists from both countries will also compare data received from a ground-based ozone monitoring network and those from the cooperative Meteor-3/Total Ozone Mapping Spectrometer (TOMS) project, which is a US instrument flown on a Soviet polar-orbiting meteorological satellite scheduled to be launched in 1991.

2.3 IMPLEMENTATION OF RESEARCH ACTIVITIES

Table 2.1 summarizes the number and type of activity conducted under WG VIII during its 15-year history. The activities are implemented in six ways: (1) symposia, meetings, and workshops; (2) joint experiments; (3) exchange of scientific and technical information and documentation on results of research on the environment; (4) joint publications; (5) data exchanges; and (6) comparisons of techniques and instruments for measuring atmospheric constituents.

Symposia, Meetings, and Workshops

Symposia, meetings, and workshops both within and outside the framework of WG VIII bring together a large number of American and Soviet scientists in WG VIII activities as well as scientists not affiliated with the program but who are involved in research in similar areas. Appendix G lists those symposia, meetings, and workshops that have been organized within WG VIII.

Although members of WG VIII have participated in meetings sponsored by other organizations, these have been treated in this report as "short- and long-term exchanges." However, WG VIII plays a very visible role in many of these "outside" meetings, and research conducted within the program has been presented at international conferences, symposia, or annual meetings sponsored by organizations such as the American Geophysical Union (AGU), the International Union for Quaternary Research (INQUA), the World Meteorological Organization (WMO), the United Nations Environmental Programme (UNEP), federal agencies (such as NOAA or NASA), universities, and non-profit organizations with an interest in climate-change issues (such as the World Resources Institute).

Although they are not included in Table 2.1, another important aspect of the program is the annual WG VIII meetings. During these meetings, US and USSR members formulate and agree on overall research objectives, review the progress of activities which were implemented since the previous annual meeting, and develop a program for the following year. Protocols summarize the discussions and, after approval by the Joint Committee Co-Chairmen, are used as the annual program plan for the upcoming year's activities.

Chapter 2

Joint Experiments

Field experiments are jointly designed and carried out by American and Soviet scientists and technicians and are conducted at remote land-based sites and aboard specially equipped research vessels. Observational experiments such as these provide scientists the opportunity to learn about each other's methodology in gathering atmospheric and oceanographic data. During these joint experiments, which typically last from two weeks to three months, US and Soviet scientists work side by side to compare each other's techniques and instruments as data are gathered. Many of these experiments are considered major achievements within WG VIII and, as such, are treated separately in another section.

Exchanges

Short- and long-term visits differ from joint experiments in that they generally involve fewer than five participants from either the US or the USSR, and discussions focus mostly on details of future experiments, exchange of research information and data, completion of articles for publication, or other coordinating work. Presentations and lectures at various universities, institutions, and government agencies also are given during these exchanges.

These visits are the predominant activity conducted in WG VIII and, in the beginning, were highly structured and formal. First, curriculum vitae of prospective exchange candidates were forwarded to the host institution at least six months before the time of the visit. This served as the basis for agreeing on the acceptability of the proposed scientists. Second, a proposal outlining the nature of the work to be performed at the host institution was provided at least four months before the visit date. This proposal was then approved by the host institution. Third, the length of visit and the number of scientists involved were to be compatible with the scope of the planned activity. Both sides agreed on these factors in each case. Finally, once the previous requirements were satisfied, the exchange visit received written approval by the WG VIII co-chairmen on both sides. At that time, the full itinerary, including site visits, was specified and agreed to. This formalism was insisted on by the US to ensure that active, contributing Soviet scientists were involved and not those who were picked for political reasons.

Recently, the organization of exchange visits has become less cumbersome. Usually, project leaders discuss future activities during a meeting or exchange visit. The project leaders submit their own protocols to the co-chairmen, at which

point they discuss the activities to be included in the official WG VIII protocol. The protocol briefly describes the scope of the activity, the number of scientists to be involved, length of time, and name and location of the facility that will be hosting the activity. "Official" invitations are issued sufficiently in advance of the visit to allow time for travel arrangements, visa acquisition, and preparation of research facilities.

Assignments to observatories or laboratories range from several days to several months or even a year, depending on the proposed research. While many of the earlier exchange visits lasted three to six months, most of the recentone have been a month or less. This situation, however, is being readdressed since extensive collaborative investigations require a longer time.

For instance, a new dimension in exchange visits has been recently implemented. In 1988, arrangements were made for the first visit of USSR post doctoral fellows to the US. These scientists were enrolled as special students for the fall semester at New York University.[12] The results of the visit itself will be discussed in greater detail in another section of this report. From February to May 1990, a NYU graduate student made a reciprocal visit to the State Hydrological Institute in Leningrad to continue research begun in 1988.

Overall, many US and USSR scientists have expressed their desire to reverse the general trend of the one- and two-week visits and increase their stay to six months or even a year. The shorter exchange visits simply do not allow sufficient time for adequate "hands on" research.

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[12]To be enrolled as special students, the Soviet scientists had to demonstrate sufficient competence in English to participate in required classes and other university activities. Tuition costs were paid by NASA and the US Department of Energy, and the scientists received a $500/month subsistence (the level currently approved by NOAA for visiting scientists) to cover meals and incidental expenses. Housing was arranged at a New York University graduate student dormitory. Actual travel and lodging expenses associated with visits to other research institutions were provided at a rate of $350/month per scientist times the number of months of the post doctoral period at NYU. Complete reports on primary research projects will be suitable for publication, and costs for publication will be assumed by the US in the event of publication in a US journal or by the USSR if published in a USSR journal.

Chapter 2

Joint Publications

Joint publications have been a significant output of WG VIII even though the translation and editing makes them considerably more difficult to complete. Usually it takes many meetings, both in the US and the USSR, to agree on the format and content of the publication and to resolve different views on controversial issues. As a result, an inordinate amount of time is required in order to allow American and Soviet scientists to reach a consensus and finalize a joint publication.

Monographs are examples of joint publications which are particularly troublesome. Although they are commissioned by participating agencies, additional funds are not set aside for contributing authors. Authors must fit these monographs into already very full schedules; and without financial appropriations for the additional work, it becomes very difficult for a scientist to set aside other projects and devote time to a monograph.

One example of this problem is the joint Monograph on Aerosols and Climate. It was originally initiated in 1979 but only just completed in June 1989. Unfortunately, over this ten-year period, new information became available in aerosol studies which was not included in this monograph, namely, the role of polar stratospheric clouds (PSCs) in the seasonal depletion of ozone over Antarctica and the biogenesis of dimethyl sulfates (DMS) in the ocean and its effect on cloud albedo. The monograph concentrates primarily on "dry" atmospheric aerosols and aerosol-related climate effects but also includes the crucially important role of "wet" aerosols, or clouds, in modifying climate. Nonetheless, it will fill the gap on assessing the progress of research carried out internationally in the atmospheric aerosol and climate disciplines.

Publications in which many joint articles have appeared include the Bulletin of the American Meteorological Society, Journal of Atmospheric Science, Climatic Change, Solar Physics, Journal of Climate, Geophysical Research Letters, and the Soviet journal, Gidrometeorologiya, to name a few. Although it is not complete because articles are in review, Appendix H contains a current list of monographs and other jointly-published materials from WG VIII. This also includes joint reports from some of the symposia, meetings, and workshops sponsored by WG VIII as well as other programs.

Data Exchanges

With the creation of the project for data management, data exchanges are now coordinated through a central source in both countries. In the US, the National Center for Atmospheric Research (UCAR) in Boulder, Colorado, was given the responsibility for implementing these exchanges, and the Soviet counterpart is the All-Union Research Institute of Hydrometeorological Information--World Data Center B in Obninsk. In addition, these institutions act as focal points for data requests and exchanges from scientists not associated with WG VIII activities as well.

The goal of the project is to create and exchange quality-controlled data sets in order to study the influence of environmental changes on climate. To reach this goal, the US and USSR data coordinators met in 1987 and established the following objectives:[13]

(1) Plan and exchange data sets which will support the other WG VIII projects and, more generally, support the needs of climate research in the US and USSR.

(2) Exchange information about the availability of data, the amount of quality control, and the history of changes in stations and instruments.

(3) Conduct research to derive refined information about climate change and fluctuations, with emphasis given to the US and USSR. This will include a detailed analysis of the effects of station moves and the growth of cities.

(4) Conduct research and exchange information on methods for data management, quality control, storage of data, gathering of data from national networks, and costs involved.

(5) Share the amount of effort required to prepare selected large data sets of marine meteorological data, precipitation, temperature data, and others.

Prior to 1986 and the establishment of this project, each of the other three projects were responsible for coordinating its

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[13]Report of the data coordinators as prepared in meetings held in Boulder, CO, September 20-23, 1987. This report was given to the author by US data coordinator, Mr. Roy Jenne, National Center for Atmospheric Research, Boulder, CO.

own data exchanges and outside requests. However, the continued growth of such exchanges required a separate project to handle this area. The types of data received include air temperature, precipitation, oceanographic reports, snow and ice variables, river flow, worldwide solar radiation, general circulation statistics, and ozone measurements, to name a few. Appendices I and J are complete lists of the data which have been exchanged between the US and USSR to date.

Equipment Calibration and Technique Comparisons

Observational systems and instruments are a necessary component of any scientific experiment but different measurement techniques require intercalibration and comparison for effective research, especially when more than one country is involved. For WG VIII, these activities lead to the development of a unified and agreed-upon method of the acquisition, analysis, and interpretation of data obtained from satellites, rockets, balloons, and other observational platforms. In some instances, instrumentation is exchanged for long-term intercomparison tests; in others, calibrations are performed using World Reference Standard instruments. Also, American and Soviet scientists familiarize themselves with each others' methodology for performing complex experiments and receive specific training on instruments being used in the experiment. More specific details on these activities will be discussed in the next chapter.

TABLE 2.1

SUMMARY OF ACTIVITIES CONDUCTED WITHIN EACH PROJECT THROUGH 1989

Project	Total	Symposia, Meetings, & Workshops	Joint Experiments	Short- and Long-term Exchanges	Joint Publications	Data Exch[1]	Instrument Calibrations & Technique Comparisons
02.08-11	98	12[2]	1	51	5	29	
02.08-12	107	7	9	46	13	26	6
02.08-13	45	4	1	24	7	9	
02.08-14	36	1		5		30	
TOTAL	286	24	11	126	25	94	6
(Percent of Total)	(100.0)	(8.4)	(3.8)	(44.1)	(8.7)	(32.9)	(2.1)

[1]Calculated as individual groups of information exchanged, i.e., in Project 14, 18 "sets" were exchanged in 1987 and 5 "sets" in 1988 for a total of 23 data exchanges.

[2]One symposium in 1978 was held in conjunction with Project 12.

Chapter 3

MAJOR ACHIEVEMENTS WITHIN WG VIII

Some of the 286 activities carried out in WG VIII are summarized in Appendices G and H. There have been major achievements within the program, some of which have contributed significantly to climate research. This chapter discusses some of these, such as the joint field experiments, the extensive climate modeling research, and instrument comparisons and calibrations. In addition, wherever applicable, I have attempted to point out unique or unusual contributions by a particular activity to many of the international scientific efforts in climate research. While paleoclimate studies have been a very active and productive aspect of WG VIII, this chapter focuses on activities which have involved actual "hands on" work. The contribution of WG VIII's paleoclimate studies to other research programs is discussed in the next chapter.

3.1 JOINT EXPERIMENTS

Joint experiments usually entail a much larger retinue of US and USSR scientists, technicians, and support personnel than for exchange visits. In addition, many of these experiments require extensive shipments of US equipment and instruments for observations, intercalibration, and comparison with similar Soviet apparatus. There have been 11 joint experiments to date: 10 at Soviet facilities and one in the US. It is this aspect of WG VIII that many US scientists in the survey would like to see expanded.

Rylsk

The first successful joint experiment for stratospheric aerosol studies was conducted during July and August 1975 at the Soviet balloon base near Rylsk, located about 500 km south of Moscow (Figure 3.1). Two US scientists from the University of Wyoming (Laramie) participated in the experiment, and representatives from the USSR included scientists from the Main Geophysical Observatory (MGO), Leningrad State University, and the Central Aerological Observatory (CAO). Data derived from this cooperative field experiment were used to determine the radiative effects of aerosols and water vapor in the troposphere and stratosphere. The experiment involved balloon, aircraft, and

Figure 3.1 Location of aerosol experiment in Rylsk (1975 and 1987).

ground-based measurements with US and Soviet instruments.[14] Figure 3.2 shows two scientists discussing the experiment. Figure 3.3 shows some of the balloons used to hoist the equipment aloft.

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[14]J. M. Rosen, N. T. Kjome, and D. J. Hofmann, "Cooperative U.S.-U.S.S.R. Balloon Flights," Bulletin of the American Meteorological Society 57 (February 1976): 1.

Figure 3.2. Dr. Vladimir Ivanov (l), Main Geophysical Observatory, discusses US and USSR balloon flight instrumentation with Norman Kjome, University of Wyoming, during the 1975 Rylsk experiment.

In July 1976, a similar experiment was performed at the University of Wyoming where a Soviet filter sampler and a particle impactor, used to measure atmospheric aerosols, were compared with US instruments. Five Soviet specialists from the Main Geophysical Observatory and the Institute of Applied Geophysics visited Laramie to conduct stratospheric aerosol sampling. They were also briefed on US procedures for measuring and analyzing samples of the stratosphere to assess the effects of chlorofluorocarbons on stratospheric ozone.

Both of these experiments were significant in two ways. First, it was not a simple task to find cooperative experiments that would be of common interest to both US and USSR scientists during the early years of WG VIII. The Rylsk-Laramie ventures provided a good starting point for cooperation in climate research. Second, these experiments enabled USSR scientists to standardize their instruments with similar US equipment, which already met world standards, and thus obtain accurate

measurements that would be acceptable throughout the international scientific community.

Despite technical and logistic problems, both sides were pleased with the results, and arrangements were made to conduct another joint study in 1987 at Rylsk to provide verification of lidar measurements using US and Soviet instrumentation. Balloon flights involving the US dustsonde and the USSR impactor and sampler were finally conducted at Rylsk on August 10 and 14, 1987.

Figure 3.3. Final preparations to US and USSR instrumentation prior to launch (Rylsk, 1975).

Although the scientists from Laramie arrived August 3, a bag of scientific equipment was lost for several days causing a delay in the flights. This delay was important because unexpected bad weather occurred, further setting back the balloon flights, and leaving only a minimum amount of time for the experiment. Equipment problems also contributed to US and Soviet frustrations. The US equipment failed halfway through the first flight so that only tropospheric data were obtained. On the

second flight, all instrumentation functioned properly, but the balloon failed at 20 km. However, this was high enough for a good comparison with the two USSR lidar systems. Unfortunately, on the last flight, all data were lost by both sides when the instruments landed in the river and sank. Past experience at Rylsk has shown that the probability of landing in water is less than 1%.

In spite of these unexpected problems, both sides agreed that the field measurements were a success. In addition, US scientists noted that USSR technology seemed to be of better quality than that which was used 12 years earlier, and the stratospheric lidar systems appeared to be similar in performance capabilities with other systems around the world.

Heiss Island

The participation of high-level Soviet scientists at Rylsk made it possible to work out the details of a newly proposed cooperative program to detect stratospheric ozone depletion called the Heiss Island Project (HIP). Field experiments were carried out from December 31, 1988, to March 15, 1989, at the A. T. Krenkel Soviet Arctic Observatory on Heiss Island located in the Franz Josef Land group of islands in the Arctic Ocean (Figure 3.4).

This was the initial phase of a two- to three-year effort involving scientists from the University of Wyoming, NOAA, the Lindenberg Aerological Observatory from the German Democratic Republic, the Main Geophysical Observatory, and the Central Aerological Observatory in Moscow. The goal was to conduct both remote (ground based) and in situ (from balloons) measurements of the depletion of ozone and study its relation to the formation of polar stratospheric clouds (PSCs) which result when temperatures decrease below -80°C within an air mass confined by the winds that circulate around the North Pole, i.e., the polar vortex, during the Arctic winter. Heiss Island is ideally suited for this research since the vortex is generally centered over this region and the coldest temperatures, necessary for PSCs, are also found here. Specifically, the major goals of the HIP were to:[15]

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[15]"Observations of Ozone and Polar Stratospheric Clouds from Heiss Island 1989," preliminary report of the Heiss Island Project supplied to the author by Dr. Vyacheslav Khattatov, Central Aerological Observatory, during his visit to Washington and Laramie, July 14, 1989.

Figure 3.4 Location of the Heiss Island Project in the Franz Josef Islands, USSR (1989).

(1) Document the variations and changes in the ozone layer over Heiss Island throughout the winter/spring season.

(2) Observe and define the conditions that lead to the formation of PSCs.

(3) Elucidate the role that atmospheric transport processes play in determining the structure of vertical ozone distribution.

This investigation was similar to the one conducted in 1988 on Antarctic ozone depletion, which directly implicated man-made chlorofluorocarbons (CFCs) as a cause of the ozone hole discovered in that region in 1985. The Antarctic study raised the question of whether a similar phenomenon could be occurring in the Arctic, albeit on a much-reduced scale. Consequently, the HIP was initiated to address this question through a variety of systematic measurements made during the entire winter/spring season.

The HIP required a tremendous amount of Soviet and American resources to make the extensive measurements necessary for a study of this magnitude. The US contributed 12 ozonesondes, a special balloon-borne device called a backscattersonde to measure aerosol scattering properties and detect PSCs, plastic balloons, training in the US of Soviet technicians operating American sounding devices, ground-telemetry receiving equipment, and data-processing equipment. In addition to the US electrochemical (ECC) sondes and modified East German ECC sondes, which measured the vertical ozone profile, total ozone was measured with a modified Dobson spectrophotometer, which employed radiation from the moon during darkness.

The USSR supplied lidar soundings of stratospheric aerosols, rocketsonde observations and ozone soundings, and radiometer soundings. In addition, two Soviet research aircraft from CAO and MGO were used to acquire atmospheric measurements. The logistics support for Heiss Island, personnel for conducting the soundings, lifting gas for the balloons, and daily meteorological information were also supplied by the Soviet side.

The extent of the local Heiss Island meteorological data is unique and, when available, will probably be the most reliable source for predicting the onset of stratospheric warming and the associated breakdown of the polar vortex. A complete analysis of the results from this cooperative effort will be published later

in English and Russian. However, some preliminary conclusions have been made as follows:[16]

(1) No anomalous spring ozone decrease similar to that observed over the Antarctic is apparent in the Heiss Island Project results for 1989.

(2) The observed winter/spring ozone variability, to a first approximation, could be explained by dynamic transport processes that advect ozone-rich air from lower latitudes to polar regions (especially during the vortex breakdown) as well as cause significant vertical motions.

(3) PSCs were observed at temperatures less than approximately -80°C and were significantly displaced from the temperature minimum.

(4) There is no apparent correlation in the structure of Type I PSCs (a backscattering ratio less than 10) and ozone inside the vortex during the polar night when evidence is limited to the Heiss Island data.

(5) These conclusions are not necessarily applicable to lower latitude regions near the edge of the solar terminator.

Figures 3.5 and 3.6 contain two examples of some preliminary results. Figure 3.5 shows the time variation of total ozone over Heiss Island as determined by four different instruments: the USA EEC sonde, a GDR OSE-3 sonde, a Brewer spectrometer, and the TOMS. Figure 3.6 is a time-height section of ozone concentration over Heiss Island as determined by both US and USSR ozonesondes. The vertical arrows indicate the days of the balloon soundings. Of particular interest is the large increase in ozone in February due to a stratospheric warming.

Concurrent with the Heiss Island Project was a NASA/NOAA-sponsored airborne expedition based out of Stavanger, Norway. Twenty-three instruments on NASA ER-2 and DC-8 research aircraft made in situ and remote observations that would indicate possible ozone depletion in the Arctic stratosphere.[17] Unfortunately,

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[16]Ibid.

[17]Richard Kerr, "Arctic Ozone Is Poised for a Fall," Science 243 (February 24, 1989): 1007-08. See also "Scientists Scan North Pole Skies for Potential Ozone Hole," Bulletin of the American Meteorological Society 70 (February 1989): 192.

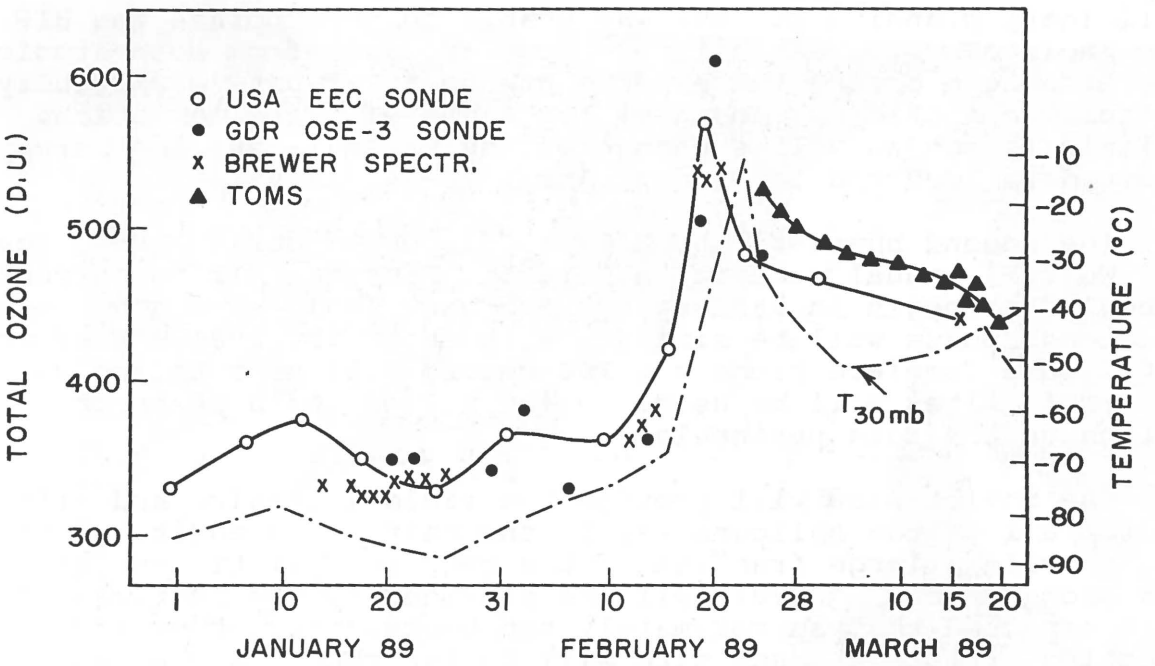

Figure 3.5 Time variation of total ozone over Heiss Island as determined by four different instruments.

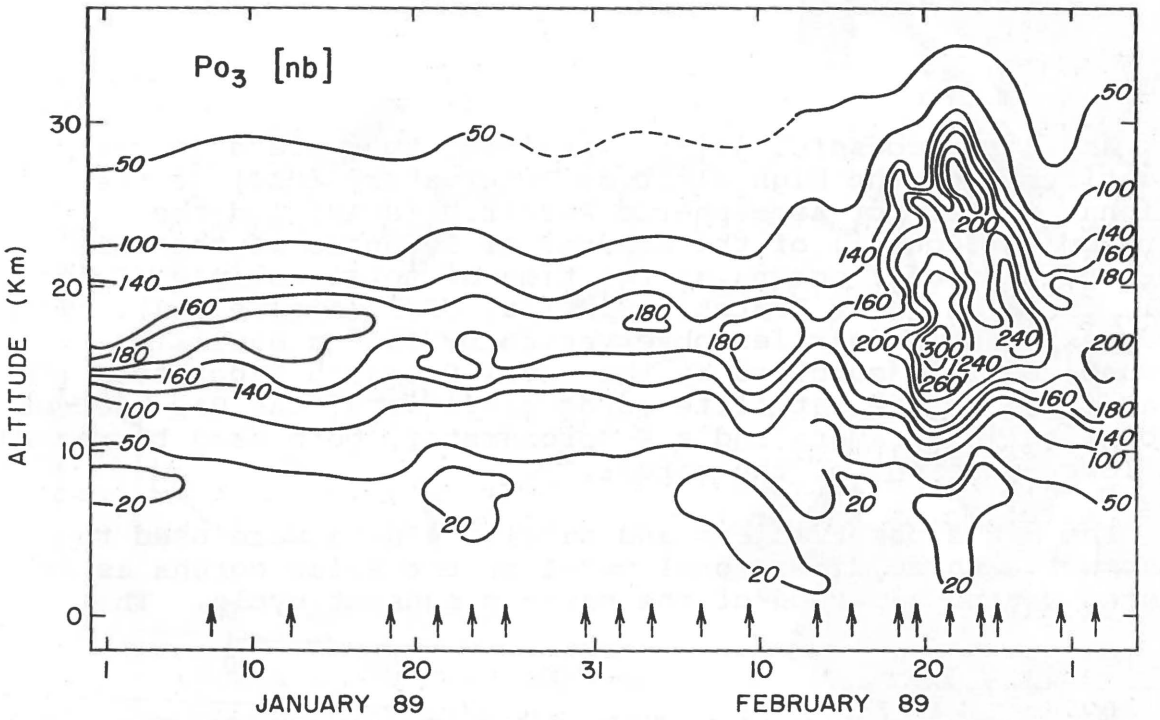

Figure 3.6 Time-height section of ozone concentration over Heiss Island as determined by both US and USSR ozonesondes.

despite WG VIII's interest in integrating both studies, preliminary planning at NASA was unable to incorporate the HIP into their own program in time. However, data from both studies were exchanged during the experiments in an effort to carefully monitor the Arctic stratosphere for signs of ozone depletion. A preliminary non-WG VIII exchange of the Heiss Island and Norway Arctic data occurred in Moscow, April 20-24, 1989.

The second phase of the HIP was discussed during the October 1989 WG VIII annual meeting in Orlando, Florida. It is currently scheduled to begin in January and February 1991. The goals of the second phase will be similar to those of the 1989 HIP except that a more complete ozone and PSC record will be obtained and two Arctic sites will be used: Heiss Island and a research station on the Kola peninsula.

The Soviet side will provide the field logistics and lifting gas for all of the balloons (as in the past). In addition, they will provide a large fraction of the required plastic balloons. Some ozonesondes, however, will be provided by the American side. It is expected that approximately ten backscattersondes for the detection of PSCs at each site will be launched. A special backscatter instrument will also be designed for installation on a high-altitude Soviet research aircraft to be employed in the 1991 campaign.

Tarma

Another successful joint experiment took place in 1981. Scientists from the High Altitude Observatory (HAO) of the National Center for Atmospheric Research (NCAR) and the Astronomical Council of the Academy of Sciences of the USSR observed the solar corona at the time of total eclipse, July 31, 1981, in Tarma (near Bratsk), Siberia, USSR (Figure 3.7). This study extended an earlier observation by adding satellite coronagraph data supplied by the Naval Research Laboratory (NRL). In addition to the satellite coronagraph data, the HAO brought a coronal eclipse camera and a K-coronameter, both used to record the lower portions of the corona.[18]

The HAO's observations and satellite data were used to construct a three-dimensional model of the solar corona as it existed during a period of the maximum sunspot cycle. This

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[18]R.R. Fisher, et al., "The Solar Corona on 31 July 1981," Solar Physics 83 (1983): 233-242.

Figure 3.7 Location of the joint experiment to study the solar corona at Tarma, USSR (1981).

experiment, although not directly applicable to climate studies, was, nevertheless, significant. It was the first time since 1966, the date of the first use of HAO's eclipse equipment, that scientists were able to see the morphology of the corona at solar (magnetic cycle) maximum. The three-dimensional model allowed American and Soviet scientists to understand better the relationship betweeen the magnetic structure of the photosphere (inner atmosphere of the sun) and density structure of the corona (outer atmosphere of the sun).

Although the joint study was, according to the HAO, very successful, contact with Soviet colleagues essentially ended with the departure of the American specialists. Since 1981, there has been little or no joint activity between the two groups. However, the HAO felt satisfied that their training and skill were well utilized in conducting the field observations from Tarma, and the data obtained has made a tremendous contribution to a 20-plus-year study of the sun's atmosphere.

SAGA-I

Despite the political tensions resulting from the Korean airlines incident, the first Soviet-American gas aerosol (SAGA-I) expedition took place from October 20-December 5, 1983. It was conducted aboard a specially equipped Soviet research vessel, the "Akademik Korolev," the largest survey vessel in the Vladivostok fleet (Figure 3.8). The "Korolev" sailed from Portland, Oregon, south to Tahiti, and back to San Francisco (Figure 3.9), collecting air and water samples containing trace quantities of freons, methane, carbon monoxide, carbon dioxide, and hydrocarbons for subsequent analysis. Scientists from the US represented Washington State University, Oregon Graduate Center, University of Hawaii, and NOAA/Geophysical Monitoring of Climate Change (GMCC). Specialists from the USSR included those from the Institute of Atmospheric Physics (USSR Academy of Sciences), the Institute of Applied Geophysics (Goskomgidromet), the Main Geophysical Observatory (Goskomgidromet), and the Far East Hydrometeorologi-cal Research Institute.

Right from the start, the expedition suffered the consequences of political tensions between Moscow and Washington. According to the US principal investigator on the cruise, the Korolev was only a day out of arriving in Portland, Oregon, and there was still some doubt by State Department officials as to whether this scientific expedition was propitious. Nevertheless, arguments in favor of the cruise prevailed, and SAGA-I did take place as scheduled. Nor did the cruise continue without additional interference from both US and French governments. Complications again surfaced when the Korolev tried to dock and

Figure 3.8 The Akademik Korolev used for all three SAGA expeditions.

fuel in Hilo, Hawaii--a scheduled stop. The State Department withdrew permission for this stop, and the Korolev was forced to head for Tahiti. Consequently, the scientists aboard the Korolev were unable to conduct ground-truth sampling with similar measurements made at the Mauna Loa Observatory (operated by NOAA/GMCC) nor was the ship able to take on fresh food, water, or additional fuel. In addition, as the Korolev approached Tahiti, the French revoked permission for the Soviet ship to dock at Papeete. At this point, the lead US scientist considered the possibility of turning toward Samoa, but the Korolev continued, nonetheless, back to San Francisco. Unfortunately, due to the withdrawal of docking privileges in Tahiti and Hawaii, potable water became very scarce: lack of fuel meant both of the Korolev's two water desalination plants could not operate.

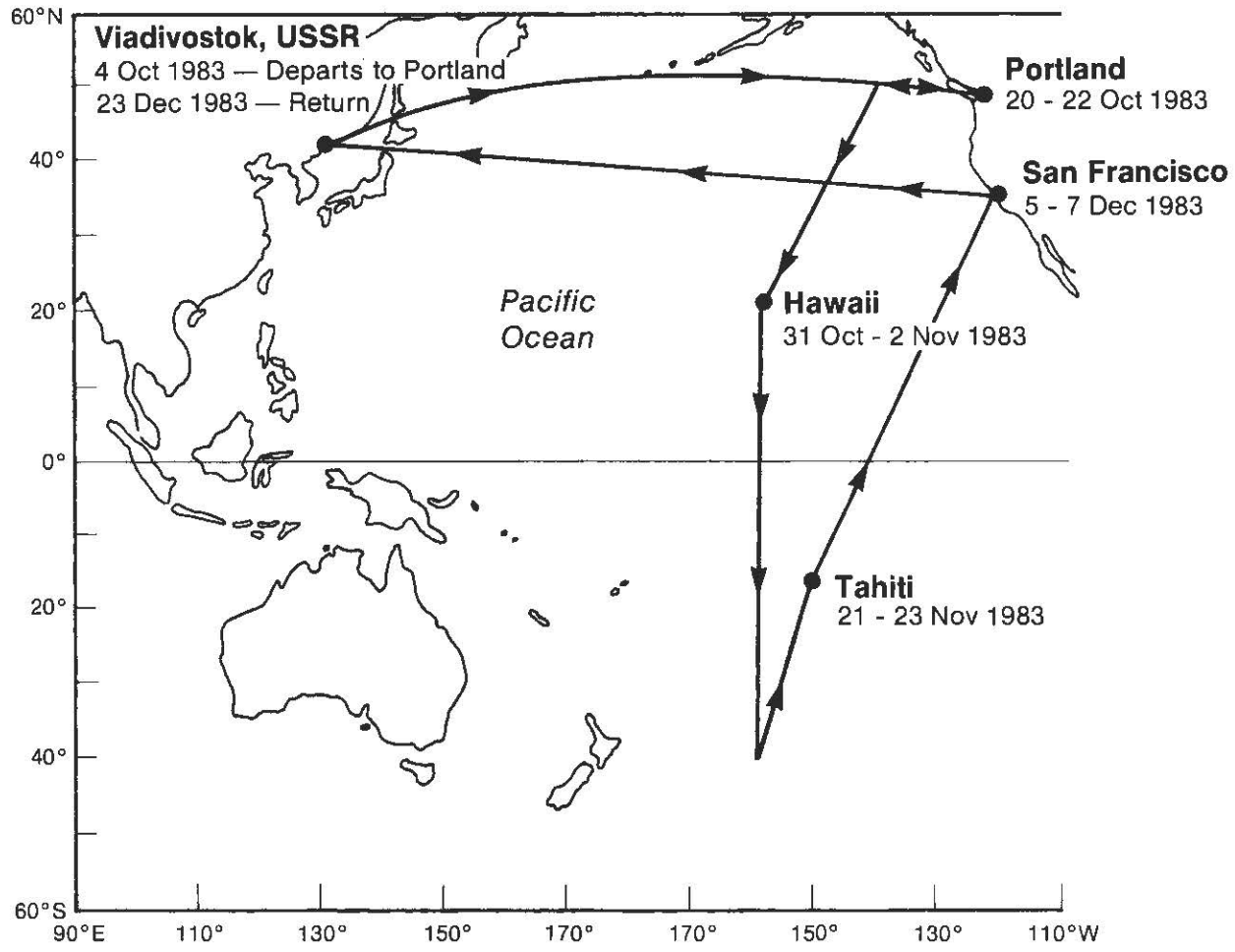

Figure 3.9 Cruise track of SAGA-I (1983).

Additional difficulties, which were not expected, arose as a result of two opposite social systems working together. For example, two of the members from the US were women. The Soviet men found it quite inappropriate that they should be unescorted on deck--regardless of the fact that they were making a scientific contribution to the overall objectives of the expedition. As a result, escorts had to be arranged each time either of the women needed to make measurements on deck. Similarly, simple and routine photocopying was a major chore, and a lot of material had to be hand copied before it could be exchanged between US and USSR scientists.

Nonetheless, despite the occasional anxieties and logistical difficulties, the expedition gathered valuable data in ocean waters that had not been investigated for 20 years. However, to date, the Soviet scientists who also made separate measurements during the expedition have not exchanged their results, so important comparisons between US and USSR data cannot be completed.

SAGA-II

Despite the difficulties which were encountered during the first expedition, a second joint oceanographic cruise was arranged for May 1-July 30, 1987. Once again, the USSR research vessel, Akademik Korolev, was used to obtain a variety of measurements of trace gases and aerosols from the marine environment and to test new analytical measurements and techniques. The overall goal was to study the air-sea exchange of these gases and aerosols and how they, in turn, contribute to global climate change.

The expedition began at Hilo, Hawaii, and continued to Wellington, New Zealand, then over to Singapore, and back to Hawaii. The exact track of SAGA-II is provided in Figure 3.10. Representative institutions from the US included the Pacific Marine Environmental Laboratory (PMEL) of NOAA, the Geophysical Monitoring for Climate Change (GMCC) division of NOAA's Air Resources Laboratory (ARL), the University of Washington, Washington State University, Scripps Institute of Oceanography (SIO), the Cooperative Institute for Research in Environmental Sciences (CIRES) of NOAA, Oregon Graduate Center, the University of Hawaii, and the National Center for Atmospheric Research (NCAR). NCAR and other university organizations were funded by NSF for this research. The Soviet participating agencies were the Institute of Applied Geophysics, the Main Geophysical Observatory (MGO), the Odessa Hydrometeorological Research Institute, the Far East Hydrometeorological Research Institute, and the Laboratory for Monitoring the Natural Environment and

Climate, all of Goskomgidromet, as well as the Institute of Atmospheric Physics of the USSR Academy of Sciences.

SAGA-II set out to evaluate the sources, distributions, and fates of climatically significant (so-called "greenhouse") trace species, i.e., nitrous oxide, methane, carbon dioxide, and CFCs, in the remote Pacific and Indian Oceans. The work involved continuous in situ sampling and measurement of gases and aerosols in the atmosphere and surface water, collection of air and water samples for subsequent analysis at shore-based laboratories, and measurement of deep-water profiles through periodic hydrocasts. This allowed US and USSR scientists to evaluate spatial and temporal trends of radiatively important trace species (RITS) with special attention paid to potential effects of the 1987

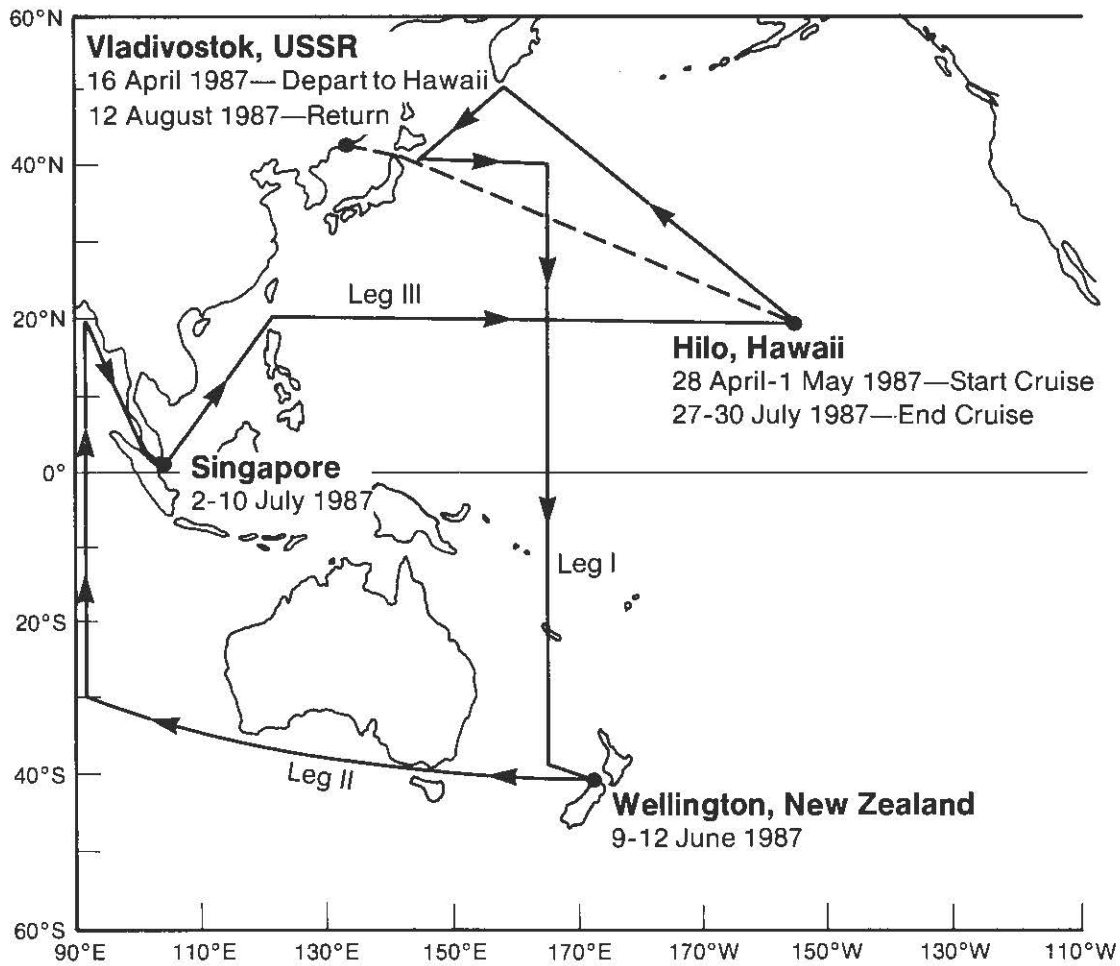

Figure 3.10 Cruise track of SAGA-II (1987).

El Nino-Southern Oscillation (ENSO) on their distributions.[19] In addition, a new technique for measuring nitrous oxide in water was tested during SAGA II. Although much of the work conducted using this technique was experimental, scientists were able to obtain a precision of 2%, comparable to measurements made by manual equilibration or extraction techniques.[20] Specifically, SAGA-II had five objectives:[21]

(1) To obtain precise and accurate measurements of the interhemispheric gradients of RITS.

(2) To correlate the atmospheric data with those from the GMCC baseline stations at Point Barrow (Alaska), Mauna Loa (Hawaii), and Samoa.

(3) To field test new techniques for measuring nitrous oxide in the atmosphere and water.

(4) To estimate the flux of nitrous oxide from the surface waters to the atmosphere.

(5) To estimate the transport of nitrous oxide to surface waters from intermediate depths.

Extensive data were obtained on the following aspects of the physics and chemistry of the atmosphere and ocean:[22]

(1) The distributions in the troposphere of chlorofluorocarbons, carbon dioxide, methane, and other trace gases which contribute to the so-called greenhouse effect were evaluated. The gradients of these trace gases at the air-sea interface were determined for various regions of the Pacific and Indian Oceans in

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[19]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, West Pacific and East Indian Oceans During the El Nino-Southern Oscillation Event of 1987, by James H. Butler and James W. Elkins, et al., NOAA Data Report ERL ARL-16 (Silver Spring, MD: Air Resources Laboratory, December 1988).

[20]"Soviet-American Gas and Aerosol Experiment (SAGA-II)," preliminary report, July 1987. A final report is expected to be completed sometime in 1990.

[21]Ibid.

[22]Ibid.

order to provide an indication of sources and sinks in the marine environment.

(2) Measurements were made of CFC 11 and CFC 12 for the first time at various depths in different regions of the Pacific and Indian oceans.

(3) Cooperative comparisons of the USSR spectroscopic and non-dispersive measurements of carbon dioxide concentration were made with the American gas chromatographic and non-dispersive measurements.

(4) Ozone concentrations in the lower atmosphere were measured, and the space-time variability of marine aerosols was investigated under a wide range of geographical and synoptic conditions. The observations of aerosol particles in the atmosphere over the ocean supported the hypothesis of a relationship between the amount of submicron marine aerosols and dimethyl sulfate (DMS) content in oceanic waters.

Despite the occasional equipment malfunctions, the results of both SAGA expeditions are significant in several respects. First, they have provided evidence for the role of the oceans as natural sources of sulfates in the marine atmosphere. Consequently, this has contributed to improved data on the current hypothesis of the DMS-cloud condensation nuclei-cloud albedo relationship. Second, the data gathered on the Pacific marine aerosol support the relationship of pollutant transport in the North Pacific to interhemispheric differences in aerosol properties. And, third, both cruises have produced some of the best work done thus far in halocarbon studies.

SAGA-I and -II were so successful that a third expedition was organized (January - April 1990). SAGA-III began at Hilo, Hawaii, continued over to American Samoa, and terminated in Singapore. The cruise track from Hawaii to American Samoa was specifically chosen in order to conduct studies of atmospheric photochemistry over a productive region of the tropical ocean and to look at interhemispheric mixing in the ITCZ (intertropical convergence zone) far from anthropogenic influences. This cruise track included five crossings of the ITCZ between 130°W and 170°W. Of the three expeditions, SAGA-III is considered the best -- mostly as a result of equipment that functioned perfectly and the acquisition of a lot of good data. Although information is preliminary at this point, research conducted in SAGA-III includes:

(1) Photochemistry in the marine boundary layer (ozone, CO, hydrocarbons, organic acids, and aldehydes).

(2) Production of aerosols, DMS, SO_2, particle-size spectrum, particle chemistry.

(3) Interhemispheric gradients and latitudinal mixing at the ITCZ of atmospheric trace gases (CO_2, halocarbons, hydrocarbons) and aerosols.

(4) Removal and mixing process connected with the ITCZ.

(5) Fluxes of trace gases from the biologically rich equatorial upwelling regions.

(6) Biological processes controlling the production of trace gases.

Unfortunately, due to the delayed arrival of the Korolev in Hawaii, a rendevous with the NOAA ship "Malcolm Baldridge" near the equator was unable to take place as scheduled. The two ships would have concurrently conducted several days of cooperative and intercomparative atmospheric photochemistry measurements.

Nonetheless, the effects of glasnost were clearly evident during SAGA-III. For example, there was significantly more computer power than what was available in 1987 during SAGA-II and, subsequently, scientists were able to monitor their results in real time. In a departure from the other two expeditions, old and new data were compared and analyzed aboard ship and instruments were intercalibrated, especially for halocarbon measurements. In addition, the cruise was a social success as US scientists were able to cement professional and personal relationships further with their Soviet colleagues.

Data obtained during SAGA-III were excellent and preliminary results may be of significance, according to one US scientist. In particular, N_2O measurements were sufficiently precise (a relative standard deviation of 0.2 percent) to detect a correlation between N_2O in the surface waters and in the atmosphere (Figure 3.11). A similar phenomenon was also documented during SAGA-II. This is important because ocean-atmosphere N_2O relationships have never been reported before except during SAGA-II and -III. Consequently, scientists may be able to use these data, along with the measurements of atmospheric temperature and humidity profiles, to estimate short-term, air-sea exchange rates, a parameter that is poorly defined at best for all gases.

In addition, atmospheric methyl chloroform (CH_3CCl_3) proved to be an excellent indicator of the ITCZ (Figure 3.12). Methyl chloroform has a reasonably short atmospheric lifetime (approximately seven years) and is produced mainly in the

northern hemisphere. These data, along with those for CFC-11, showed this zone of interhemispheric mixing to range from a few degrees latitude to as much as 20 degrees latitude. Preliminary viewing of meteorological data shows this to be related to air-mass movement in the two hemispheres, but an evaluation of the air-mass trajectories will need to be made before any conclusions can be drawn. Nonetheless, these data will be useful in estimating the degree of variability in interhemispheric exchange and perhaps for assigning error to estimates of exchange times and global production rates of halocarbons.

The data obtained during SAGA-II and -III will be useful in resolving questions concerning the fluxes and transport of radiative, atmospheric trace gases. In addition to helping scientists evaluate air-sea exchange and atmospheric processes, these data complement measurements from NOAA's continuous monitoring network by providing spatial "snapshots" of latitudinal gas distributions.

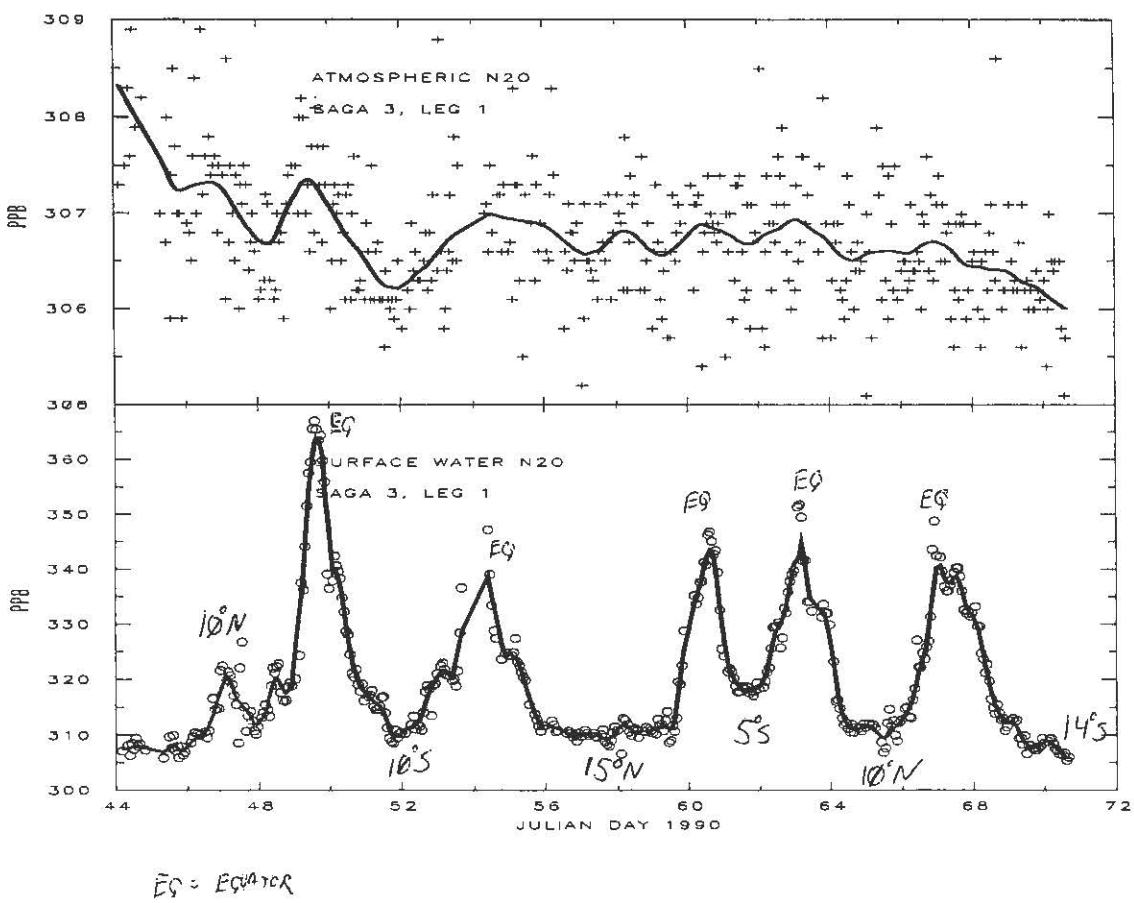

Figure 3.11 SAGA-III: Atmospheric and surface N_2O (preliminary data).

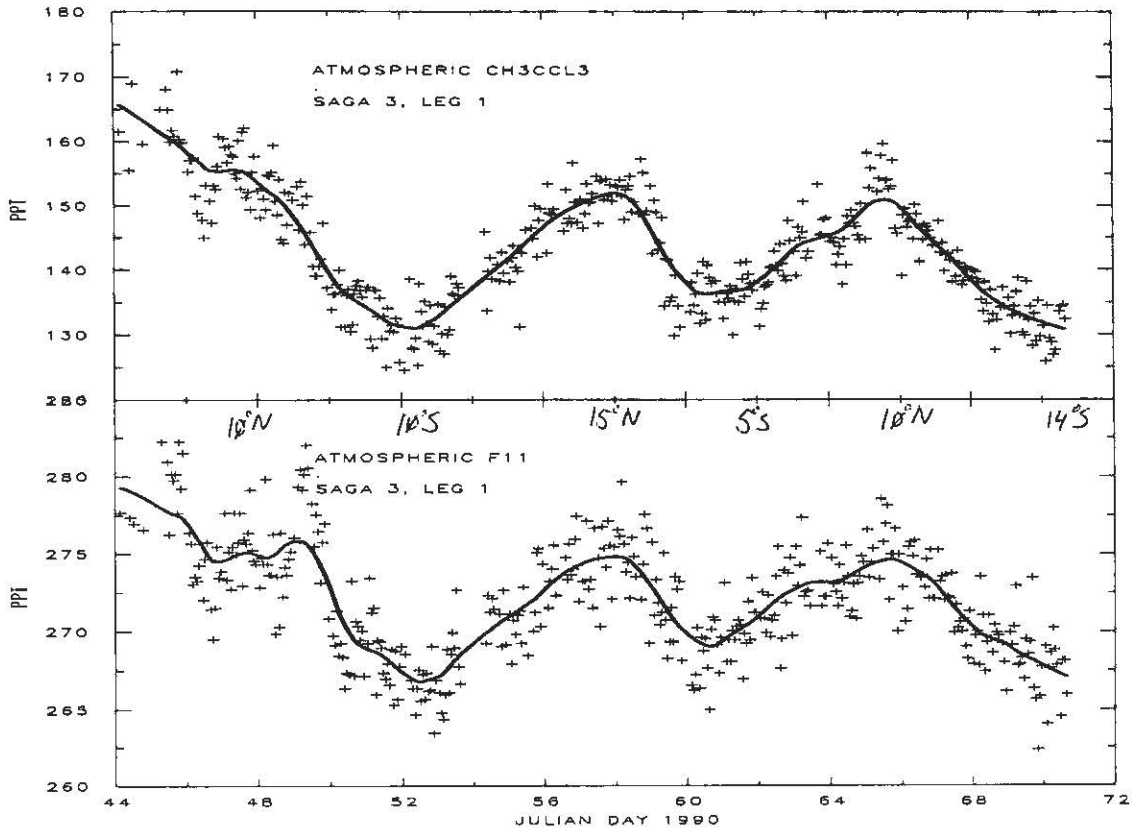

Figure 3.12 SAGA-III: Atmospheric methyl chloroform and CFC-11 (preliminary data).

Lake Baikal

Lake Baikal is a symbol of national pride within the Soviet Union. It is the world's deepest lake (more than 1 mile) and contains the greatest volume of any fresh water lake in the world. Unfortunately, it has also become a source of recent environmental concern. In July 1988, Soviet and American scientists jointly conducted research to determine Lake Baikal's chemical characteristics of trace constituents, including CFCs (Figure 3.13). This was a multilateral effort and included scientists from Scripps Institute of Oceanography (La Jolla, California), Canada's Institute of Ocean Sciences, the Institute of Applied Geophysics (Goskomgidromet), and the Institute of Limnology (Siberian Branch of the USSR Academy of Science), which generously provided the use of their vessel "Vereshchagin."[23]

[23]R. F. Weiss, V. M. Koropalov, and E. C. Carmack, "Ventilation of Lake Baikal," abstract provided to the author.

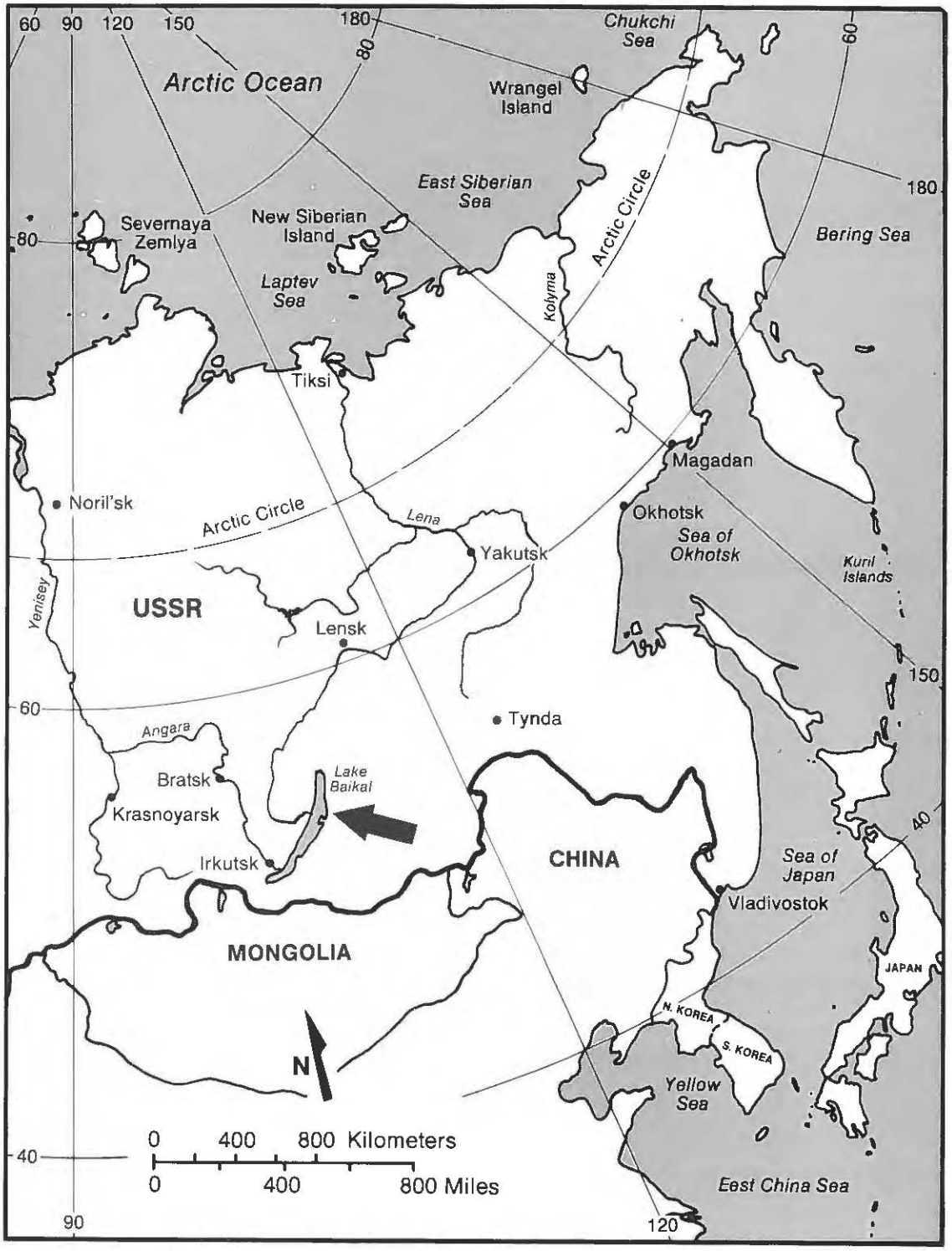

Figure 3.13 Location of joint experiment at Lake Baikal, USSR (1988).

Originally, it was thought that Lake Baikal turned over twice a year; however, preliminary investigations show that the rate of renewal may be more on the order of once every 10-15 years. This could be very significant in terms of Lake Baikal's ability to ventilate trace elements at the surface, i.e., circulation of fresh water so as to retard pollution. The longer it takes Lake Baikal to turn over, the longer it will take for the lake to naturally rid itself of pollutants.

Certainly, this new study could have very serious implications for the health of one of the Soviet Union's natural treasures. Further investigation has been proposed for 1991, at which time US and USSR scientists will try to understand better the means by which deep mixing processes occur in Lake Baikal by measuring its physical and chemical changes. It is of interest to note, also, that the National Geographic Society has indicated their interest in participating in this second phase of research on Lake Baikal -- a first within not only WG VIII but the entire bilateral, and further indication of the widespread interest developing over international environmental issues.

Tadzhik Republic

Another joint experiment was recently conducted in Central Asia. During September and October 1989, US and USSR scientists spent 40 days studying aerosols and radiation budgets in the desert region of the Tadzhik Republic of the USSR (near Dushanbe). Specifically, the Dushanbe Natural Environment (DUNE) experiment took place in the Kafirnigan River Valley from the Amu Darya River (which borders Afghanistan) to Dushanbe (Figure 3.14).

This joint US/USSR investigation included US scientists from the GMCC division of NOAA, the University of Colorado, Georgia Institute of Technology, Utah State University, US Geological Survey, University of New Mexico, and Florida State University. In addition to the US and USSR members, the University of Paris in France was also represented. From the USSR, participants represented the Tadzhik Republic Hydrometeorological Service (Dushanbe), the Main Geophysical Observatory (Leningrad), the Institute of Atmospheric Physics of the USSR Academy of Sciences (Moscow), Leningrad State University, the Institute of Experimental Meteorology (Obninsk), Umarov Physical-Technical Institute (Dushanbe), Institute of Atmospheric Optics of the USSR

Figure 3.14 Location of joint experiment in the desert region of Tadjikistan, USSR (1989).

Academy of Sciences (Siberian Branch), and the Institute of Physical Chemistry of the USSR Academy of Sciences (Moscow).[24]

Sources of dust are found in arid to semiarid areas of continents in both hemispheres. However, the drylands in Central Asia are second only to the Sahara for dust generation potential. Until now, the dust emissions from Central Asia have been investigated less than have those of some less important dryland areas. The objective of this field experiment is to gain further knowledge of the consequences that might result from an increase in dust flux to the atmosphere due to the increased aridity of soils as the global climate warms. The links between dust and climate are reciprocal: climate can affect local soil conditions that may favor dust generation while dust can affect the albedo and radiation balance of the earth and, thereby, control climate on a larger scale. Dust transport may extend far, causing the effects of dust to be global.

To achieve the objective, the investigation consists of three complementary components:

(1) The detailed investigation of the mechanics of dust formation by means of instruments placed on the ground surface that can link dust flux to soil and air-flow conditions. The measured data are entered into a mathematical model for a description of the dust formation process.

(2) A thorough chemical-element characterization of suspended aerosol particles, both close to the ground and above the ground for representative sampling of ambient air. Statistical analysis of the chemical characteristics can lead to a determination of the sources of dust from different soil types.

(3) A comprehensive set of measurements of radiation characteristics of both the atmosphere and the ground surface by means of in situ and remote sensing instruments. Additional information from aircraft and satellites may also be used in the interpretation of radiative properties in relation to the presence of dust.

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[24]John W. Winchester and Dale A. Gillette, "Dust in Soviet Central Asia, Its Chemical Reactions with Acid Air Pollutants, and Deposition of Toxic Metals to Ecosystems and Man," overview of joint US/USSR experiment prepared for a discussion at the Aspen Institute Berlin Meeting, June 1989. Also based on Dr. Winchester's field trip report to the USSR, February 1989.

Although data analysis is only preliminary at this point, this cooperative experiment will give US and USSR scientists a new understanding of dust characteristics in Central Asian regions that have, up to now, constituted a serious gap in scientific knowledge. Moreover, a new appreciation will be obtained of the extent to which dust and its constituents may be linked to several important environmental effects, including soil erosion, desertification, pollution transport, and potential changes in climate.

Beringia

Project 11's first joint experiment was conducted in July and August 1989 at lake sites in the far eastern Soviet Union north of Magadan in the Kolyma Region (Figure 3.15). This area is important for obtaining long-term data on high-latitude climate change because Beringia, the region spanning the Bering Strait from northwestern North America to northeastern Asia, remained largely ice free when continental glaciers covered most high-latitude regions of North America and Europe. Paleoclimate interest in Beringia dates from the 1950s and, more recently, data from eastern Beringia has been used to test ideas of global climate change. However, more data are needed from far western Alaska and virtually all of far eastern Siberia to examine important features of model-simulated climate for all of Beringia.

In collaboration with the North-East Interdisciplinary Scientific Research Institute, a division of the Far-East Center of the Academy of Sciences of the USSR, members from Ohio State University, University of Washington, and the University of Alaska initiated the collection and analysis of palynological and paleolimnological data from far eastern Siberia. This was the first of three phases toward compiling a fossil data set comparable to that now available for eastern Beringia.

Specifically, Soviet and American researchers raised parallel cores from six lakes in the northern Kolyma region of Siberia. These lakes, located in the northern taiga, are now accessible by surface vehicles. Some of the more remote lakes, however, are reachable only by helicopter. These cores will be used to explore the implications of the Siberian and Alaskan contribution with respect to GCM simulations of regional paleoclimates.

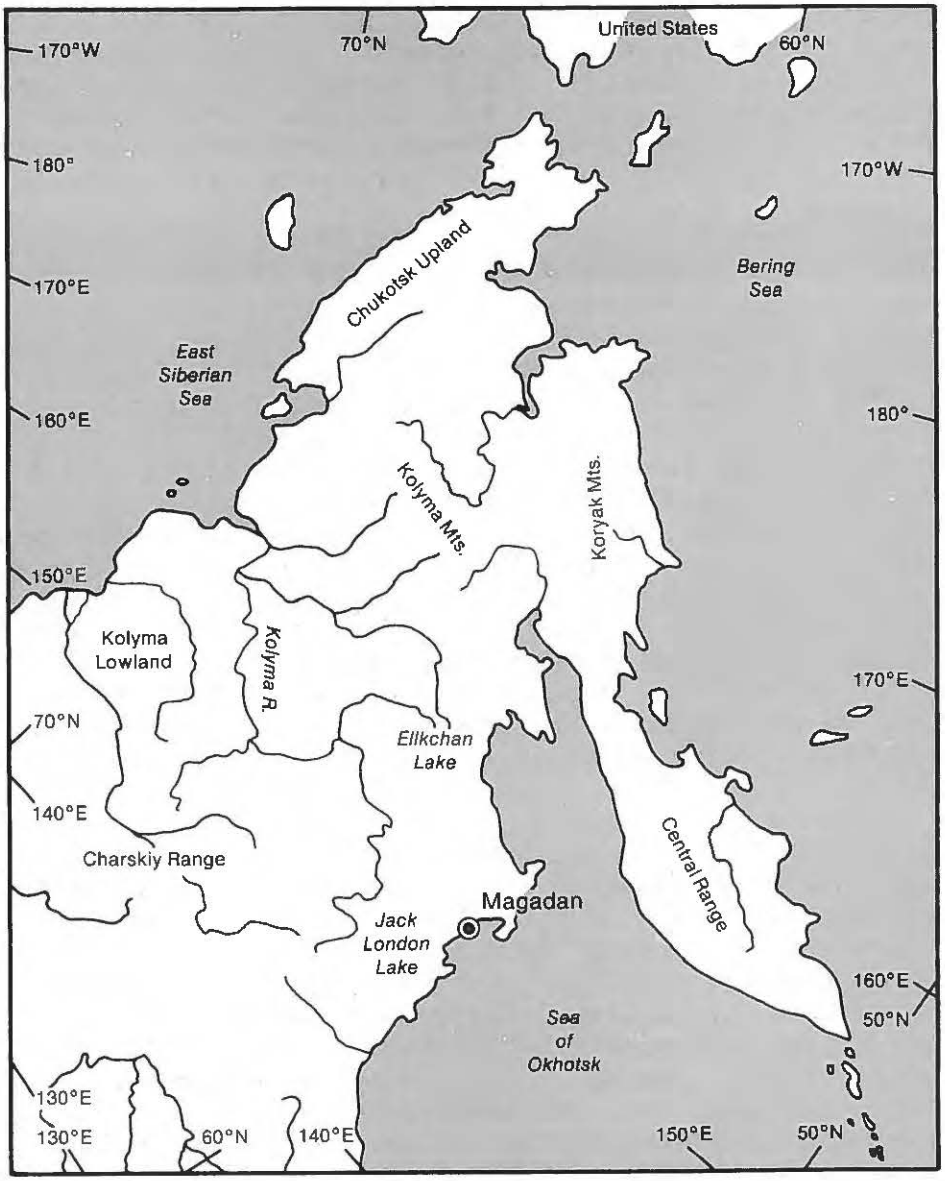

Figure 3.15 Location of joint experiment in the Kolyma region of far eastern Siberia, USSR (1989).

A four-man Soviet team spent a month (July and August 1990) in the US to conduct field work in the Seward Peninsula of Alaska, duplicating the efforts in Siberia. The sediment cores from Siberia and Alaska will be analyzed independently by Soviet and American laboratories. However, the Alaskan field study will allow a first comparison of the Siberian results.

The second phase will be devoted entirely to the analysis of Siberian and Alaskan lake sediments. During phase three, Ohio State University will organize a workshop to review the results and implications of the joint research. It will also address the broader question of climatic change in the region and suggest further collaborative work.

Western Siberia

Another joint field study which will be proposed for 1991 is a three-year effort to measure methane and out-gassing in the high latitudes of the northern hemisphere. Important high latitude methane sources are found in North America adjacent to the Hudson Bay and the moist tundra areas of Alaska. In the Soviet Union, very high methane fluxes are predicted for the Pripat Marsh area of Western Siberia and the boreal, unforested bogs of the far northeastern territory across the Bering Strait from Alaska. In order to ascertain the existence of these methane fluxes, US and USSR scientists will conduct field experiments in late July or early August 1990 near Tyumen, Nadym, and the Gyda Peninsula (Figure 3.16). An intensive field study currently focuses on the Minnesota and Alaska wetlands. It is the intent of WG VIII to conduct a comparable effort to measure directly the seasonal methane fluxes from the high-latitude wetlands of the Soviet Union.

This assessment is critical because methane is known to contribute strongly to the radiative equilibrium of the planet through its infrared opacity. Methane also plays a major role in maintaining the photochemical state of both the lower (troposphere) and the upper (stratosphere) levels of the atmosphere. However, unlike the CFCs, which are entirely anthropogenic and subject to regulation by international accords, the sources of methane are poorly quantified in terms of anthropogenic (rice, cattle, sheep, fossil fuels) versus natural (swamps and bogs) sources. Therefore, attempts to "regulate" the rate of increase of atmospheric methane by international agreements will be problematical at best.

It is anticipated that this cooperative US/USSR research program will provide a reliable assessment of the potential magnitude and timing of this methane flux in the Soviet Union. In addition, this study will be incorporated into the scheme of the International Global Atmospheric Chemistry (IGAC) program under the Canadian-Soviet project which focuses on northern wetlands. Subsequent research will then be conducted on a tri-lateral basis between the U.S., Canada, and the Soviet Union.

Figure 3.16 Location of the methane field study in western Siberia, USSR (1991).

The components of this program are broken down into four areas:[25]

(1) Joint field expeditions

(a) Conduct in situ flux measurements in representative boreal wetland environments to determine the mean and variable flux of methane and its isotopes (^{13}C and ^{14}C) as a function of season.

(b) Conduct surveys of the extent and climatic vulnerability of methane hydrate deposits in both terrestrial permafrost and submarine environments within the Arctic basin.

(2) Establish and maintain a network of atmospheric measurement stations at high latitudes to track the changing flux of carbon (CO_2, CH_4, and CO) between the atmosphere and the biosphere in response to climatic change. This network would extend and strengthen the existing sites in the US and USSR where carbon cycle trace gases are being measured, either by infrequent grab samples or at stations where personnel maintain automated instrumentation for continuous monitoring (Figure 3.17).

(a) Exchange primary standards for carbon cycle trace gases; field intercalibration of measurement systems (gas chromatographic, spectroscopic); exchanges of scientists, technicians, and students for research and training.

(3) Exchange critical data on the carbon cycle at high northern latitudes

(a) Data bases on the extent and character of high latitude soils and vegetation types are required for high-resolution modeling of the boreal methane source.

(b) Data on the distribution and magnitude of methane hydrate deposits within the Arctic, and on other

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[25]Richard H. Gammon, "Assessing Present and Possible Future Sources of Methane in the High Latitudes of the Northern Hemisphere," a draft plan for US/USSR cooperative research, prepared by NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, August 10, 1988.

industrial and agricultural activity at northern latitudes which can significantly influence the atmospheric methane concentration (e.g., exploration and production of fossil fuels such as coal, oil, and natural gas; natural and deliberate forest fires; domestic and industrial wood burning; populations of wild and domestic animals that are ruminants).

(4) Cooperative carbon cycling program

(a) Joint development of carbon cycle models validated against present-day fluxes and distributions of carbon cycle trace gases at high northern latitude, and of predictive models to assess the magnitude of possible future increased fluxes of methane and carbon dioxide from the Arctic in response to global warming.

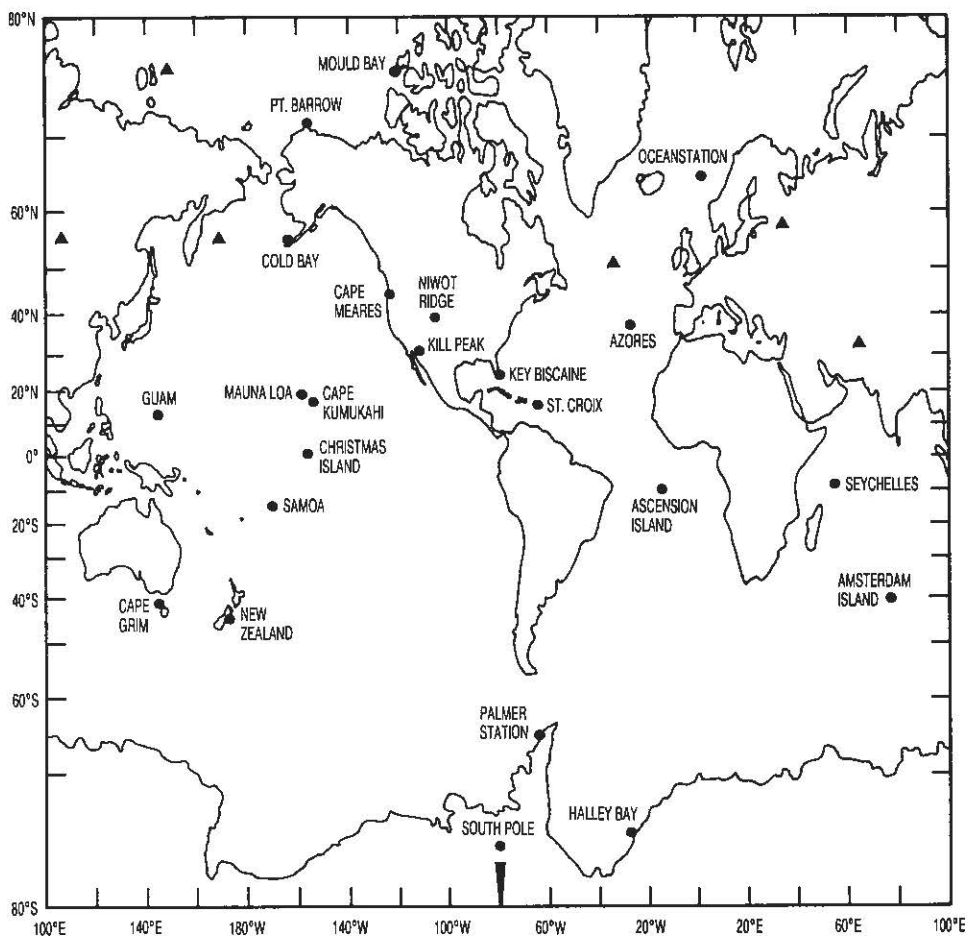

Figure 3.17 Network of flask sampling sites (USSR stations are indicated by ▲).

Joint experiments are becoming more commonplace in WG VIII's overall program and have proven to be a good mechanism for both US and USSR scientists to acquaint one another with current research methods and discuss particular issues or problems. These exchanges have been successful not only from a scientific standpoint but also for developing personal relationships. These individual associations have endured over the years to form a strong basis for continued mutual trust and support within the program which has led to even greater scientific openness and cooperation. Figure 3.18 is just one example of the "social" side of these exchanges. In addition, as the more extensive field studies are incorporated more frequently into WG VIII's program, research on climate-related issues will continue to be strengthened. At any rate, these cooperative exchanges will help keep open the channels of communication that politics so often fails to do.

Figure 3.18 King Neptune holds his court. US and USSR participants aboard the SAGA expeditions participate in a ceremony in honor of crossing the equator.

3.2 CLIMATE MODELING

Comparisons of US and USSR models have been an active part of the program since 1975. Currently, there are four principal Soviet GCMs which are used at (1) the Computing Center of the Academy of Sciences, Moscow; (2) the Hydrometeorological Center, Moscow; (3) the Department of Numerical Mathematics of the Academy of Sciences, Moscow; and (4) the Main Geophysical Observatory, Leningrad. In the US, the principal GCMs are those used at: (1) University of Illinois at Urbana-Champaign; (2) NOAA's Geophysical Fluid Dynamics Laboratory, Princeton, NJ; (3) NASA's Goddard Institute for Space Studies, New York; and (4) NSF's National Center for Atmospheric Research, Boulder, CO.

A recent assessment undertaken in 1988 by Oregon State of the four USSR GCMs shows that Soviet computers do not yet permit the use of GCMs "to simulate the potential climatic changes induced by increases in atmospheric greenhouse gases."[26] Nothing comparable to US computers used for climate research has been available in the USSR. Consequently, this has severely restricted the evolution of general circulation models as a tool for climate research.

While computer development and technology in the USSR has not kept pace with that in the US, the dialog in the area of climate modeling has, nevertheless, resulted in combining the resources of both nations for estimating climate change. For example, Soviet scientists excel in the use and derivation of empirical methods, including extensive paleoclimate analysis for practically all of Asia and Europe. They also excel in theoretical mathematical methods and finite difference applications. In addition, there are a number of USSR scientists who have made truly outstanding contributions to the field, and other groups exist within the USSR that have the potential. However, computer resources as they exist now in the USSR are likely to seriously constrain any significant progress in the area of modeling.

The first three-month exchange of both US and USSR scientists took place in late 1975. A scientist from the University of Utah collaborated with colleagues from the Main

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[26]"The Simulation of CO_2-Induced Equilibrium Climatic Change Using the General Circulation Model of the Leningrad Main Geophysical Observatory: A Collaborative US/USSR Study," a request for computer time made to NCAR by Michael E. Schlesinger, Oregon State University, January 1989. A copy of this request was furnished to the author by Dr. Schlesinger.

Geophysical Observatory and Leningrad State University in analyzing and modeling factors affecting radiation transfer in the atmosphere. Soviet scientists from the Computer Center (Siberian branch of the USSR Academy of Sciences, Novosibirsk) visited NCAR in Boulder, CO, to discuss models being developed in the US as well as those in use in the USSR.

During the summer of 1977, a scientist from the University of Missouri visited the Main Geophysical Observatory to begin formulating simple seasonal climate models assumed to be useful in studies of temperature field responses to variations of different climate-forming parameters. This visit resulted in two publications in Russian: an article in the 1978 issue of the journal Meteorologiya u Gidrologiya (Meteorology and Hydrology) and a brochure published in 1980 by Goskomgidromet.

Two longer exchanges (six months) took place in 1978. During one exchange, scientists conducted research involving a theoretical method for producing a three-dimensional cloud distribution derived from the analysis of total cloud amount, solar radiation, and long-wave radiation at the top of the atmosphere. During this project, a detailed data set was provided by the Soviet side that consisted of monthly mean global distributions of total cloud amount for all of 1974. The entire data set has proved to be very valuable to several US climate research groups. US climate modeling techniques were studied during the second exchange, and an extended integration of a Soviet atmospheric model was conducted on the Cray-1 computer at NCAR.

A multiyear effort began in 1979 in which a Soviet two-dimensional climate model was compared with a similar 2-D model developed at Lawrence Livermore National Laboratory (LLNL) and a 3-D GCM at Oregon State. This was an interesting exercise since no 2-D model had been extensively compared with 3-D models. Including the Soviet climate models in the project allowed US scientists to understand the performance of the Soviet model and exchange ideas about validation and sensitivity studies.

In 1984, a different twist was added when new physics were provided by US modelers to insert dust and smoke into the Soviet model for global simulation studies of the "nuclear winter" effect. Unfortunately, due to the mysterious disappearance of the head of the climate research laboratory of the Computing Center of the USSR Academy of Sciences in 1985 while attending an international conference in Cordoba, Spain,[27] much of this

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[27]Andrew C. Revkin, "Missing: The Curious Case of Vladimir Alexandrov," Science Digest, July 1986, pp. 32-43.

activity has decreased. To date, neither the US nor USSR government know exactly how or why Dr. Vladimir Alexandrov disappeared. Nonetheless, research has continued in this area with the Institute of Atmospheric Physics and the Computing Center (both of the USSR Academy of Science) under the auspices of the Scientific Committee on Protection of the Environment (SCOPE) sponsored by the International Council of Scientific Unions (ICSU).

In 1980, WG VIII began to consider climate models as a tool to assess the sensitivity of various climate states to the concentration of carbon dioxide. A workshop on the climatic effects of increased atmospheric CO_2 was held in Leningrad in 1981, during which time scientists of both countries agreed on the qualitative effects of anthropogenic activities on the atmosphere.

Although four earlier symposia had taken place on CO_2 and climate, which helped US and USSR scientists assess the research and viewpoints of each other, the workshop was held to evaluate the status of research in order to define a detectable "fingerprint" or "signature" that would constitute unequivocal evidence of climate response to increasing concentrations of atmospheric CO_2 and resolve the questions and differences which had arisen between US and USSR scientists on this issue. As a result, this workshop set the stage for continued exchanges of scientific research in climate modeling that focuses on the CO_2-climate relationship.

Subsequently, a four-pronged approach to considering the climate aspects of the CO_2 issue was developed in 1981 by LLNL, a DOE laboratory:[28]

(1) A variety of improved and realistic climate models, particularly in terms of their representation of the oceans, would be used for simulating regional and temporal responses to increasing CO_2.

(2) Past climate situations, particularly warm periods, would be studied as possible analogs for the warmer conditions that increased CO_2 concentrations are expected to induce.

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[28]"Climate Research Priorities in the DOE CO_2 Program," preprint of a paper presented at the Workshop on the Climatic Effects of Increased Atmospheric Carbon Dioxide, Leningrad, USSR, June 15-20, 1981, by Dr. Michael C. MacCracken, Lawrence Livermore National Laboratory, May 1981.

(3) The results of model and past climate studies would be combined so that comprehensive scenarios could be assembled for use in assessment studies.

(4) A research program would be developed that would seek early evidence to determine whether climate is responding to increasing CO_2.

Since then, simple and complex models continue to be developed, improved, and tested within the WG VIII program. Major improvements in the models have included the treatment of the oceans, cryosphere, clouds, radiation, boundary layer physics, and the land surface and biota. WG VIII is now supporting a number of cooperative US-USSR modeling efforts to increase the focus on CO_2-climate studies. These include:

(1) The University of Illinois and the Main Geophysical Observatory are performing two equilibrium simulations of CO_2-induced climate change with the MGO atmospheric GCM/mixed-layer ocean model: one to simulate the equilibrium climate with a CO_2 concentration of between 300 and 330 parts per million volume (ppmv), and one with double this concentration ($2xCO_2$).

(2) LLNL and Atmospheric and Environmental Research, Inc. (AER), have an ongoing comparison of atmospheric chemical and radiative models with the Main Geophysical Observatory which used to study global effects on ozone and climate. There is a need for very detailed representation of infrared radiation in the atmosphere, particularly the importance of the overlap of H_2O, CO_2, and ozone absorption bands, and the need to consider the radiative effects of other combustion-generated gases.

(3) New York University and the State Hydrological Institute are constructing a combined energy balance/carbon-cycle model that incorporates a two-dimensional schematic ocean circulation in order to investigate the need for consistent treatment of the ocean in the two types of models. It was at NYU that two USSR scientists recently conducted WG VIII's first post-doctoral research, as discussed earlier.

Since 1988, there has been considerable interest in determining the usefulness of paleoclimate studies and reconstructions as an analog for future climate change caused by greenhouse warming, and as a means of demonstrating and evaluating the ability of climate models to represent past climates. Current integration efforts undertaken in WG VIII will

be reflected in the study being led by LLNL and the State Hydrological Institute. This report, "Prospects for Future Climate: A Special US/USSR Report on Climate and Climate Change," will address not only the study of ancient climates but also that of the modern record to determine the predictability of future climates. Table 3.1 lists the contents of the report and the contributing authors. The report is based on US and USSR work sponsored by WG VIII and contains:

(1) Improved documentation of climate changes in the extratropical Northern Hemisphere during past warm periods extending back several million years.

(2) Increased availability and detailed analyses of data sets on global-scale changes in temperature and precipitation over the past 100 years.

(3) Measurements and geological estimates of carbon dioxide changes over past geologic periods.

(4) Intensified reconstructions and analyses of paleoclimatic conditions, using both empirical and numerical modeling approaches.

(5) Development of improved theoretical capabilities (models) for studying climate change and for projecting future climate conditions.[29]

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[29]Michael C. MacCracken, Alan D. Hecht, Mikhail I. Budyko, and Yuri A. Izrael, eds., "Prospects for Future Climate: A Special U.S./U.S.S.R. Report on Climate and Climate Change," a review draft of this report was provided to the author, February 1990.

TABLE 3.1

Prospects for Future Climate: A Special US/USSR Report on Climate and Climate Change

Chapter	Contributing Authors USSR	USA
1. Introduction	Irina Borzenkova Mikhail Budyko	Raymond Bradley Robert Etkins
2. Past Changes in Global Climate	Eleonora Byutner George Golitsyn Yuri Izrael	Peter Gleick Martin Hoffert Thomas Karl
3. Present-Day Changes of Global Climate	Igor Karol Kira Kobak Vladimir Kotlyakov	John Kutzbach Michael MacCracken Cynthia Rosenzweig
4. Changes in Atmospheric Composition	Gennadi Menzhulin Igor Shiklomanov Andre Velichko	Michael Schlesinger Donald Wuebbles
5. Theoretical Estimates of Greenhouse-Gas-Induced Climate Change	Konstantin Vinnikov	
6. Empirical Methods for Estimating Future Climatic Conditions		
7. The Impacts of Climate Change for Water Resources and Agriculture		
8. Prospects for Future Climate		

3.3 CALIBRATIONS AND COMPARISONS

Instrument calibrations and technique comparisons have been a significant component of WG VIII since 1977. Many agencies, universities, and institutes are generally involved; but the dominant US and USSR facilities in this area are NOAA's GMCC division, the USSR Main Geophysical Observatory (MGO), and the Central Aerological Observatory (CAO).

From June 1977 to June 1978, the USSR M-83 ozone filter photometer was evaluated relative to the US standard Dobson spectrophotometer. The purpose of this evaluation was to determine whether a relatively simple and inexpensive instrument such as the USSR M-83 could be successfully used for routine monitoring to determine ozone trends. During another visit to MGO in late 1977, Soviet scientists were presented with an American-made ECC surface ozone meter and were provided appropriate training and instructions for its use. The visit also gave US scientists an opportunity to learn about the non-dispersive infrared analyzer technique employed by the USSR for measuring total column CO_2.

A project in 1978 established a USSR Dobson spectrophotometer as a secondary standard reference instrument for total ozone measurements in the USSR. The USSR Dobson spectrophotometer was checked, calibrated, and modernized electronically relative to the World Primary Standard Dobson instrument maintained by NOAA's GMCC division in Boulder, Colorado. This allowed the USSR to calibrate the M-83 filter ozone meters which are routinely employed for total ozone measurements. Figure 3.19 shows two USSR scientists involved in the calibration process. In order to assist the USSR in contributing to global CO_2 monitoring and research, a three-week project in 1979 provided information to USSR scientists on the construction of a semi-automated apparatus for analyzing CO_2 flask samples, along with appropriate training for effective use of the apparatus.

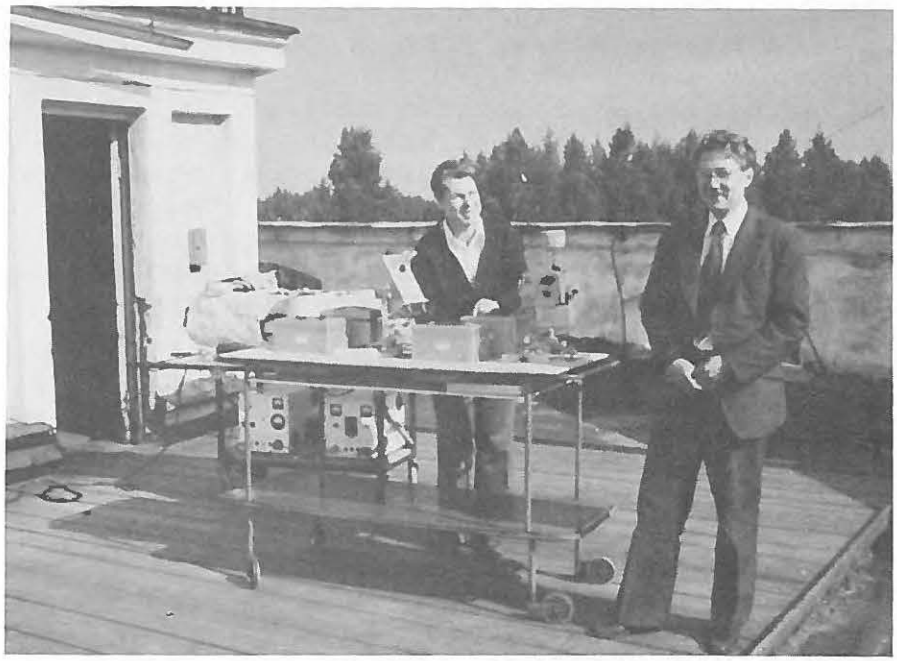


Figure 3.19 Vladimir Kovalyev (l) and Alexander Yegorov (r), Main Geophysical Observatory, with instruments for measuring atmospheric turbidity at the experimental base in Voeikovo, about 25km east of Leningrad (August 1978).

During this same period, a USSR M-83 ozone meter was delivered to the NASA Wallops Flight Center. This project was part of a plan for continuing comparison measurements of ozone begun in 1976 at NOAA's baseline station in Mauna Loa, Hawaii. Ozone and turbidity were measured with both US and USSR instruments for comparison and calibration. This comparison with the USSR ozone meter and the US Dobson spectrophotometer, as well as the US Foltz photometer and a USSR turbidity meter continued in 1980 at Wallops Flight Center.

There was continued assistance to Soviet specialists for global CO_2 and ozone monitoring and research in 1982. Eight tanks of CO_2 calibration gases were provided to Soviet scientists to carry out controlled analyses. Eight more flask samples were given to the USSR upon completion of the SAGA-I expedition in 1983. In addition, the apparatus built by the USSR for flask sample analysis, a copy of one fabricated at NOAA's GMCC laboratory in Colorado, was checked. The USSR also received an ECC ozonesonde for useful balloon measurements of the vertical distribution of ozone. This was subsequently used in the 1987 joint experiment at Rylsk, USSR, which was discussed earlier.

More recently, with the advent of satellites for monitoring ozone, another method for measuring vertical profiles of ozone has been introduced in WG VIII. The Umkehr method, a German term for "turning around," was established to validate satellite data. The USSR now wants to improve a new inversion algorithm developed by them which would make better use of the statistics. The adequacy of this new Soviet inversion technique will be tested on Umkehr and ozonesonde data provided by NOAA in future activities.

The question of aerosols, as indicated earlier, has gained in attention because of their role in climate change. WG VIII participates in a program to develop an agreed-upon international procedure for calibrating lidars which are used to study stratospheric aerosols. Despite the fact that there is no international agreement on calibration methods at present, WG VIII has exchanged lidar data obtained in the US and USSR and continues to develop a program of lidar calibrations. This program emphasizes regular and precise intercalibrations of standards and intercomparisons of actual measurements. Lidar sites which monitor stratospheric aerosols are located in the US at Mauna Loa (Hawaii), Urbana (Illinois), and Boulder (Colorado). In the USSR, these sites are located at Tomsk and Dolgoprudny (Figure 3.20).

Ideally, a global lidar network would be extremely beneficial, given the crucial need for some way to monitor aerosol distribution over the great continental land masses. Unfortunately, it is not easy to get quantitative lidar

Figure 3.20 Location of lidar sites in Tomsk and Dolgoprudny, USSR.

measurements because there are so few countries with established lidar sites. Consequently, the World Meteorological Organization is not considering the network as a near-term prospect at this time.

However, one of the issues addressed at the July 1989 conference of the International Association of Meteorology and Atmospheric Physics (IAMAP) in Reading, England, was that of developing an agreed-upon method of lidar calibration for international standardization. The general opinion of the conference favored such a network, and a document will be prepared and presented at the International Laser Radar Conference which will take place this July in Tomsk, USSR. At that time, it is anticipated that an international procedure for calibrating lidars will be established and a central data-storage facility designated.

Because of their contribution to a potential lidar network, the USSR has expressed a high level of interest and suggested that scientists meet in Obninsk prior to the Tomsk conference in order to prepare the formal document, which will then be carried back to the International Radiation Commission for implementation.

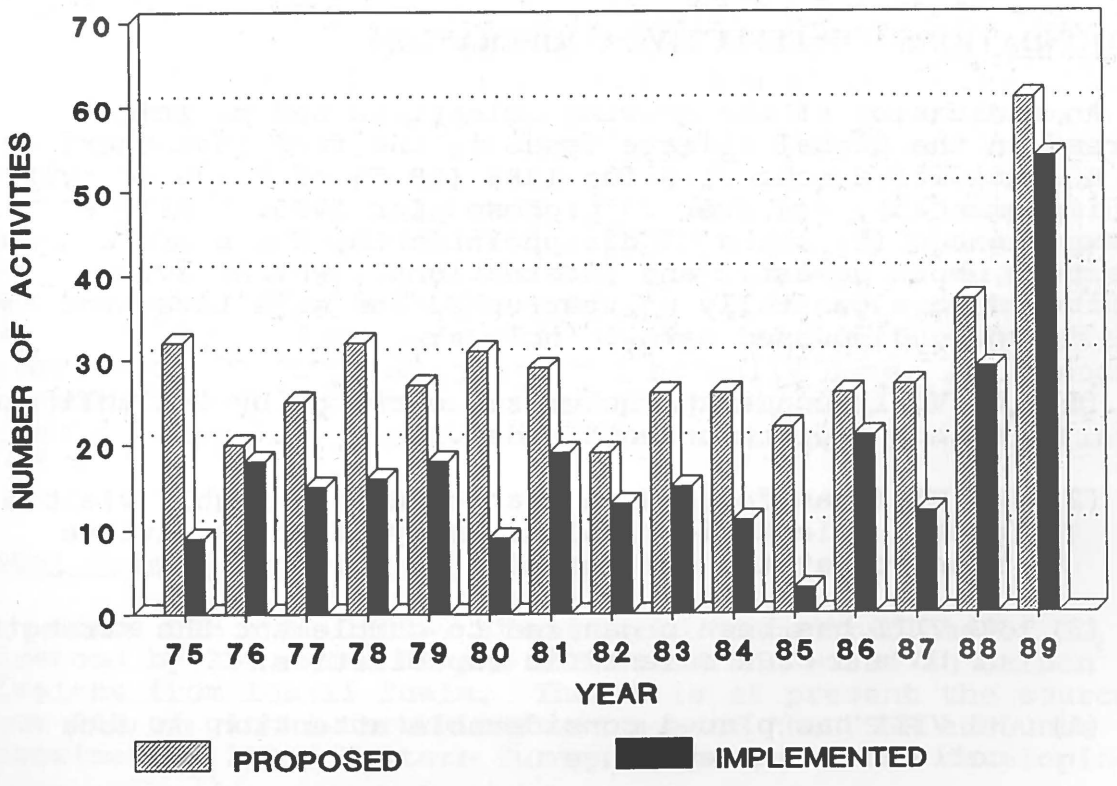
From July 1987 to June 1989, ozonesonde observations were obtained at the USSR base station, Mirny, in Antarctica. These observations were significant in that they contributed to the study of ozone depletion in Antarctica during 1988. The US provided 60 ozonesondes for measurements at the Soviet Antarctic station in 1987 and an additional 10 along with related equipment in 1988. In an effort to continue these efforts in 1990, 50 ECC ozonesondes were shipped to Moscow. It is anticipated that the USSR will compare measurements made with both East German and US ozonesondes. A meeting to analyze all ozone measurements made by both US and USSR Antarctic stations is scheduled for fall 1990.

Chapter 4

FACTORS CONTRIBUTING TO, AND LIMITING, WG VIII'S EFFECTIVENESS

For 15 years, American and Soviet scientists have cooperated in joint studies of atmospheric chemistry, solar variability, and climate change. Despite fluctuations in US-USSR political relations and the discontinuation of the Joint Committee for six years, WG VIII activities have continued each year without interruption (see Figure 4.1). For example, regardless of the call for cessation of all personal cooperation with the USSR in 1978 after the arrest of Orlov and Shcharansky,[29] many US participants in WG VIII continued their professional interactions, as is evident from the continuation of activities shown in Figure 4.1.

Figure 4.1 WG VIII Activities



[29]Linda L. Lubrano, "The Political Web of Scientific Cooperation Between the U.S.A. and USSR," in Nish Jamgotch, ed., Sectors of Mutual Benefit in U.S.-Soviet Relations (Duke University Press: Durham), 1985, p.61.

Because of President Carter's restrictions on scientific cooperation after the 1979 Soviet incursion into Afghanistan, the Joint Committee ceased to conduct its annual meetings. Nonetheless, WG VIII activities continued, albeit on a reduced basis and without the guidance of the JC. The tensions created by the 1983 Korean Airlines incident placed WG VIII's first joint cruise in jeopardy of being postponed. However, the Soviet-American Gas Aerosol expedition (SAGA-1) took place as scheduled and is a testament to the high-level support for WG VIII.

It is interesting to note that, despite the continuation of WG VIII's activities throughout the past 15 years, no single year witnessed 100% implementation of the proposed activities. This was due to a variety of factors, such as insufficient financial support, conflicting professional commitments of both US and USSR scientists, and other "unexplained" circumstances. These "unexplained" incidents, although occurring in the early years of the program, did limit WG VIII's effectiveness and will be dealt with later in this chapter.

4.1 FOUNDATIONS FOR EFFECTIVE COOPERATION

An indication of the growing scientific and political interest in the global climate issue is the fact that there were over 60 activities scheduled for 1989 (88.5% of these activities were implemented), and over 70 proposed for 1990. While WG VIII has experienced its share of disappointments, there are a number of factors, both domestic and international, which have contributed to a generally uninterrupted and effective program. These factors, discussed below, include:

(1) WG VIII became characterized early on by its mulitple-agency support on both sides.

(2) WG VIII has focused on meaningful and highly visible global scientific problems, many of which involve research at the cutting edge of science.

(3) WG VIII has been organized to complement the strengths of US and USSR scientific capabilities.

(4) WG VIII has placed considerable attention on data collection and exchange.

(5) WG VIII has produced a significant output of jointly published papers and research successes.

(6) The US-USSR environmental agreement has, until recently, been the only major continuing cooperative program between the two countries in atmospheric and earth sciences.

In addition, there is substantial interest in the climate-change issue which necessitates continued collaboration between the US and USSR in climate research. For instance, new developments within the US and USSR have elevated environmental protection to a priority issue in each country. In addition, many international programs have also been established since 1985 in an effort to develop global policies to prepare for climate change.

Multiple-Agency Support

In 1975, the US Co-Chairman of WG VIII tried to give a government-wide flavor to the US side of the program, bringing in the National Science Foundation (NSF) in particular, and also NASA, EPA, the Department of Energy (DOE), and the Department of Transportation (DOT) as much as possible. Multiple-agency support is not often done in the US and was even more difficult to achieve in the USSR. For example, when visiting the USSR, attempts were made to establish contact with scientists outside of Goskomgidromet, but these first attempts were always met with a negative response, "No, it cannot be arranged." However, as US scientists continued to persist, Hydromet began to relent, and occasionally scientists from the USSR Academy of Science or other institutes outside of Hydromet would be allowed to participate in the exchanges. This multiple-agency support was not particularly easy for Hydromet because either there were real bureaucratic obstacles or it just simply was not normally done. This modos operandi has now become much more accepted, and, as evident in Appendix F, many US and USSR institutes are now participating in WG VIII.

Global Scientific Problems

Since the late 1800s, atmospheric concentrations of CO_2 have increased by 25%. The US and USSR lead the world in carbon emissions from fossil fuels. The US is at present the source of about 26% of global carbon emissions, and the USSR accounts for approximately 21%. Western Europe, Japan, and the developing

countries account for 17%, 5%, and 18% respectively.[30] The US is also the major producer (about 30% of the world's supply) and consumer of CFCs. Scientists from the US and USSR have conducted collaborative research which has contributed to a better understanding of greenhouse warming and stratospheric ozone depletion, and WG VIII provides a mechanism for such joint research activities.

Recently, the issue of global climate change has reached a new level of domestic and international awareness. This has indirectly contributed not only to WG VIII's success but also increased the visibility of its activities. In the US, for instance, global climate change issues received considerable attention in the 100th Congress, with more than 20 air- and climate-related bills introduced.[31] A number of these bills encouraged further international cooperation to address these important issues.[32]

Many US and USSR scientists in WG VIII have actively participated in the increasingly frequent international debates and assessments that address climate-change issues. Not only have their scientific results been presented during major conferences but some have also participated in extensive joint studies in which WG VIII data have been used to support up-to-date and comprehensive international assessments.

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[30]Irving Minzter, Global Climate Change and Energy Policy, a report of the Strategic Planning Seminar on the Long-Term Implications of Climate Change (Washington, D.C.: World Resources Institute, January 5, 1988): p. 108.

[31]"The U.S. Global Climate Change Program Will Take a Major Step Forward," Ocean Science News 30, 10 December 1988. See also "Federal Coordination Bill Approved," Global Climate Change Digest 1, October 1988, p. 37.

[32]Congress, Senate, National Global Change Research Act of 1989, 101st Cong., 1st sess., S. 169; Congress, Senate, Global Warming Response Act of 1989, 101st Cong., 1st sess., S. 603; Congress, Senate, Global Environmental Protection Act of 1989, 101st Cong., 1st sess., S. 676; Congress, Senate, Stratospheric Ozone and Climate Protection Act of 1989, 101st Cong., 1st sess., S. 491; Congress, Senate, World Environment Policy Act of 1989, 101st Cong., 1st sess., S. 201; Congress, Senate, Global Environment and Climate Change Assessment Act of 1989, 101st Cong., 1st sess., S. 251; Congress, House of Representatives, Global Environment Research and Policy Act of 1989, 101st Cong., 1st sess., H.R. 980.

For instance, some members of WG VIII contribute to the Ozone Trends Panel reports that critically assesses the influence of natural and anthropogenic phenomena on the chemical composition and physical structure of the stratosphere. The Ozone Trends Panel was formed in October 1986 by NASA in collaboration with NOAA, the Federal Aviation Administration (FAA), WMO, and UNEP. In addition, WG VIII played a major role in enlightening USSR scientists on the ozone issue, which helped develop a consensus toward policies on worldwide CFC production which are being implemented through the Montreal Protocol. Furthermore, over the past three years in particular, there have been frequent environmental symposia, conferences, and meetings sponsored by the WMO, UNEP, and governments of concerned nations in which many WG VIII participants have been presented as key speakers.

US/USSR Scientific Capabilities Complemented

WG VIII activities have been organized to complement each nation's research capabilities. Where Soviet scientists excel in theoretical and empirical analysis, American strength lies in computer climate modeling. Combined Soviet and American climate studies, particularly related to paleoclimate data, permit comparison of model simulations and empirically derived reconstructions of climates of the past.

The Soviet Union has a large fleet of oceanographic research vessels that are able to remain on station for long periods of time in order to do mid-ocean monitoring. The US does not have ships capable of maintaining stations for months at a time in order to take oceanographic and aerological soundings. Also, the NOAA fleet is smaller than it has been in the past and overcommitted to do work of a general oceanographic nature. The new ships that are built are designed for coastal work.

The Soviet Union's Arctic and Antarctic research stations, which carry out sophisticated meteorological observations used to study stratospheric ozone depletion, are also well positioned to assist research activities both within the framework of WG VIII and in other programs.

Data Collection and Access to Information

Another important foundation for effective cooperation within WG VIII has been the emphasis on data collection and access to information. Because climates vary spatially and temporally, no one point measurement can define global climate. Organized data on the amounts, trends, and characteristics of

trace constituents and their effects are, for the most part, still very sparse. The creation of a more encompassing global monitoring system, producing compatible data, requires country-to-country interaction, mutual studies, similar equipment, and data exchanges. Interaction with the USSR is crucial since much of their data are still difficult to access and translate, and publications remain obscure to western scientists. Thus, a concise summary of available data is required.[33]

Since the USSR occupies one-sixth of the world's land mass, a global monitoring system would be virtually useless without the cooperation of the Soviet Union and access to its data. Many American climatologists are quick to affirm that it would be very difficult to study global climate change without USSR cooperation. For instance, data sets from interior Eurasia and from the Eurasian Arctic are very important and not available in any other way but through WG VIII's collaborative efforts. Access to Soviet paleoclimate data has been difficult, but progress continues to be made with the acquisition of very valuable information. In addition, the SAGA-II cruise was particularly useful in that US scientists would not have been able to sample waters in areas near Kamchatka without this cooperation. As a result, valuable data were gathered for current and future carbon dioxide research.

Output of Joint Publications

Although it is only one aspect of the activities within WG VIII, joint publications have also contributed toward effective cooperation. Successful "science" today is measured by published articles or books. WG VIII has maintained a consistent level of annual publications by US and USSR authors. These joint publications have contributed to WG VIII's success for the following reasons:

(1) They have led to a better understanding in the Western scientific community, in particular, of state-of-the-art research conducted by Soviet scientists.

(2) They have presented different perspectives on hotly debated climate-change issues, in particular, the use of paleoclimate data as an analog for the future.

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[33]"U.S. Researchers See Historic Shift in Relations with Soviet Scientists," The Chronicle for Higher Education (June 22, 1988): A1, A8-A10. See also "Recent Pollen Spectra and Zonal Vegetation in the Western USSR," Quaternary Science Reviews 2 (1983): 281-321.

(3) They have presented unique and significant results for many new areas of scientific interest, such as the three-volume monograph on US and Soviet late Quaternary environments, the SAGA reports, and the monograph on aerosols.

A Surviving Agreement

Another important factor contributing to effective cooperation between WG VIII participants is that the US/USSR Agreement on Environmental Protection was, until recently, one of the few surviving and active bilateral agreements. Scientific cooperation between the US and USSR, in general, has traversed down a very rocky road.[34] The environmental agreement itself suffered from the imposition of restrictions, as mentioned earlier, but it has been one of the most durable and scientifically rewarding of the many agreements that emerged in the 1970s.

Probably the most salient feature of the agreement, and within WG VIII in particular, is its ability to keep non-technical issues at a minimum and maintain a relatively apolitical quality which has permitted exchanges to survive difficulties between Washington and Moscow far better than most of the other scientific and cultural programs that flourished during detente. In addition, cooperation for the most part has been most productive in fields in which the USSR has a well-developed potential, such as wildlife and nature conservation, climate analysis, and earthquake prediction.[35]

The continuation of WG VIII exchanges, especially after the ban imposed on JC meetings in 1979, demonstrated that a reservoir of interest remained among American participants. In addition, the budgetary constraints placed on EPA during the Reagan administration put the program in an even more precarious position, since it was clear that environmental issues were not high-priority topics. Fortunately, the issue of climate never dwindled in importance, as did some of the problems addressed by the other working groups; and participating agencies maintained a

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[34]Linda Lubrano, op. cit., pp. 50-82. See also Catherine P. Ailes and Arthur E. Pardee, Jr., Cooperation in Science and Technology: An Evaluation of the U.S.-Soviet Agreement (Boulder, CO: Westview Press, Inc., 1986).

[35]Donald R. Kelley, "American-Soviet Cooperation on Environmental Protection and Conservation," in Nish Jamgotch, ed., Sectors of Mutual Benefit, pp. 102-126.

relatively steady level of support for WG VIII activities, as indicated by Figure 4.1. More important for WG VIII, the earlier years of frustration have been replaced by a sense of excitement as a result of an increasingly heightened global awareness of environmental issues, and climate change in particular.

4.2 LIMITATIONS TO COLLABORATION

Implementation of WG VIII activities has not been without difficulties and frustrations. As in previous surveys on the overall quality of Soviet science,[36] WG VIII also presents its own sobering story. US scientists indicated that the main areas of Soviet strength are physical theory, intensive routine measurements, soil microbiology, infrared technology and modeling, obtaining ozone data of excellent quality, gathering paleoclimate data, analysis and compilation of data sets, applied math, math statistics, and turbulence analysis.

There are a number of areas, however, in which US scientists indicated many deficiencies. The most glaring of these were numerous references to substandard instrumentation and insufficient computer capabilities, both software and hardware. Some US scientists have estimated that computer development is still 10-15 years behind US technology. One US modeler indicated that it is nearly impossible to accomplish effective modeling in the USSR; and it is difficult, for national security reasons, to give Soviet modelers access to US supercomputers.

Another area of disappointment and frustration, previously touched upon earlier, was the issue of access to Soviet facilities. In the days before "glasnost," access to some locations in the USSR was severely limited, and some US scientists were denied access even after their itineraries had been approved and reciprocal visits had previously been allowed at US facilities.

For instance, in 1977, all requests to visit the Institute of Atmospheric Optics in Tomsk and the Pacific Geographic Institute in Vladivostok were refused. In addition, certain key Soviet scientists were restricted to where they could travel not only within the Soviet Union but also on an international level. This created an unbalanced program in that meetings and symposia had to be scheduled in the USSR because these scientists could meet with their counterparts only in their home cities and almost never in the US.

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[36]Linda Lubrano, op. cit., p. 57.

Appendix G indicates that of the 24 major symposia, workshops, or other significant WG VIII meetings, 21 have been held in the USSR and only 3 in the US. Overall, twice as many activities took place in the USSR,[37] but since 1986 there has been a shift toward a more balanced program, with equal numbers of activities in both countries. For example, of the more than 70 activities planned for 1990, approximately 31 will take place in the US and 33 in the USSR.

Still another limitation on the effectiveness of research conducted in WG VIII is the slowness of the publication progress and, in particular, data exchanges. Although the Data Management project was created in 1986 to simplify and improve data exchanges, US scientists still complain that data exchanges and procedures need to be improved.

Some US scientists have become discouraged with Soviet promises of data and indicate that the flow of information is only one way. For example, the lack of Soviet data from the SAGA-I cruise made it less desirable for some US scientists to participate in the second cruise. Flask samples of carbon dioxide were left with Soviet scientists, but US researchers never received the results of their analysis. At a minimum, US scientists should have received other samples in the flasks for analysis, but the flasks themselves were not returned.

SAGA-II produced a lot of good data on halocarbons, but it still took 18 months to get the Soviet data. Even when the data were received, they were not considered first quality because of older versions of Soviet equipment used aboard the research vessel.

This lack of two-way flow also makes joint publication difficult. At present, there is no established post experiment procedure for scientists to visit institutions that have participated in major joint experiments. The disadvantage of this is that US and USSR participants do not have the opportunity to discuss their research in person, and communication then becomes tedious and time consuming. Post experiment visits in both countries are, therefore, warranted in order to facilitate two-way data exchange and subsequent joint publications.

More or less implicit in the foregoing is the great concern on the issue of communication itself. Although communications

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[37]This includes not only the significant meetings but also the short- and long-term exchanges and joint experiments. There were 161 such activities (see Table 2.2); of these, 107 took place in the USSR and 54 in the US.

with Soviet scientists have improved in general since 1985, present methods continue to be frustrating and discouraging. Letters take four to six weeks to reach their destination. Telexes or cables are slow to generate responses. Facsimile is not well established in the USSR. Even the time difference between the US and USSR (e.g., eight hours between Washington, D.C., and Moscow) makes telephone communications difficult. This places constraints on administering the research activities properly. It is difficult to arrange joint projects, exchange data, or even discuss the results of an activity with such slow methods of communication. Certainly, one of the most important services that WG VIII could implement is a reliable and efficient system of communication between US and USSR participants.

Such a system does exist, and WG VIII has just begun to avail itself of the advantages offered through electronic mail. However, the use of electronic mail, or e-mail, is a new frontier for WG VIII. As such, the usefulness of this new technology will be discussed in greater detail in the final chapter of this report.

On a more positive note, even in areas where limitations exist, many of the scientists surveyed indicated that the cooperative program is worthwhile and makes a significant contribution to climate research. Some recognize that it is not so much one person that is to blame, for example, when Soviet data are not forthcoming, but that the Soviet system itself is still restrictive.

4.3 PROSPECTS FOR CONTINUED COOPERATION

More recently, the personal attention given potential greenhouse warming and stratospheric ozone depletion by both President Ronald Reagan and General Secretary Gorbachev during their summit meeting in November 1987 provided a new and unprecedented impetus for further cooperation within WG VIII. The two leaders approved a bilateral initiative to pursue studies in global climate and environmental change, and they called for a detailed study on the climate of the future. This special report, discussed previously, is scheduled for completion in 1990. The "behind the scenes" activity that led to this historic statement by the two leaders reflected a sense of confidence

based on 15 years of actual joint endeavors in environmental protection since 1972.[38]

The umbrella environmental protection agreement is a mechanism for the US and USSR to positively address environmental problems, shared by both countries, and cooperate with each other to help resolve such issues. In addition, changes in domestic policy within the US and USSR, as well as international programs related to climate change, have escalated since 1985.

Increased Environmental Awareness Within the US and USSR

Protection of the environment in the USSR is now a high priority. A first step was taken in February 1988 with the creation of the State Committee for the Protection of the Natural Environment (Goskompriroda), which was established in recognition that a radical restructuring of environmental protection measures was required.

For the first time within the USSR, there is a defined agency that is organizationally divorced from the economic ministries. For instance, the new environmental agency was given broad rights and responsibilities in formulating and implementing policy, setting norms and standards, managing and monitoring natural resource use, and enforcement. Subsequently, restrictions were placed on new industrial development in polluted areas. For example, a decree was issued on April 13, 1987, to cease timber operations on Lake Baikal and to convert the mills to furniture factories producing no pollutants. In addition, the northern river diversion plans were discontinued because the environmental side effects would negate the promised benefits. Also, the depletion of the Aral Sea for irrigation has lowered its level by 40 feet over two decades. Even Gosplan was directed to include environmental protection in its five-year Plan for Economic and Social Development of the USSR.[39] However,

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[38]According to the project leader for 02.08-11 (and the special report lead coordinator), the original Soviet rationale for this report was that the bureaucracy did not want to just be supporting science but wanted some specific political benefits from the 10-15 years of joint activities in this area. On the other hand, the same explanation of US motives could be made, and it would sound just as plausible to Soviet ears.

[39]Nicholas A. Robinson, "Perestroika and Priroda: Environmental Protection in the USSR," final draft provided by author prior to inclusion in Pace Environmental Law Review, January 1989. For additional information concerning the environmental issue within

Goskompriroda's attention is not currently focused on global warming. Climate-change research and participation in the Intergovernmental Panel on Climate Change (IPCC) is the responsibility of the USSR Academy of Science and Goskomgidromet.

The role of the USSR in the Arctic is potentially very significant, particularly for efforts to protect the Arctic environment; and the new attitude expressed by Soviet officials concerning scientific research in the Soviet Arctic is important. The new reforms have created a more favorable climate for Arctic scientific research on bilateral and multilateral bases, and they have opened up new opportunities for joint study within WG VIII.

In the US, Congress has promoted and directed federal efforts to address climate-change issues. The National Climate Program Act of 1978 directed the Department of Commerce to provide for a coordinated national program in climate. More recently, the National Climate Protection Act of 1987 directed the President, through EPA and the Department of State, to develop policy options for dealing with greenhouse climate change and for coordinating international activities. In addition, a plethora of new bills are also being introduced calling for remedial action, for example, the National Energy Policy Act, the Global Environmental Protection Act, and the Global Greenhouse Warming Prevention Act.

Other events which exemplify US governmental concern over the climate change issue were the request by concerned senators to the National Academy of Sciences (NAS) to review policy issues related to greenhouse warming and the request by Congress for the EPA to conduct studies on the impacts of climate change and possible options to respond to greenhouse warming.[40]

The new environmental consciousness was also reflected in the confirmation of William Reilly, a leading environmentalist, as EPA Administrator, which was a major reversal of eight years of environmental inaction under the Reagan Administration.[41]

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the USSR, the reader is also directed to Barbara Jancar, Environmental Management in the Soviet Union and Yugoslavia (Durham: Duke University Press, 1987) and Charles Ziegler, Environmental Policy in the USSR (Amherst: University of Massachusetts, 1987).

[40]Eliot Marshall, "EPA's Plan for Cooling the Global Greenhouse," Science 243 (March 24, 1989): 1544-45.

[41]Leslie Roberts, "Reilly Vows Environmental Activism," Science 243 (February 10, 1989): 731.

Lest the reader be given the impression that this "new environmental consciousness" has provided the impetus for The White House to act accordingly, it should be pointed out that the current administration has, in reality, tried to take a cautious, middle-of-the-road stance. It is attempting to balance the potential (but still unpredictable) problem of climate change against the equally worrisome fear that remedial actions (i.e., costly and major changes to our energy economy) may prove not only unnecessary but economically harmful.

Regardless of the current position taken by the US administration, the inexorable increase in greenhouse gas emissions into the atmosphere ensures that the climate change issue will not go away in the foreseeable future. This fact plus the increased attention by the Soviet Union in mitigating environmental degradation within its borders and that given to climate-change issues by the US in general has set the stage for expanded scientific cooperation between the US and USSR. For example, the USSR has proposed a new and separate agreement on climate. This topic is addressed in the concluding analysis, but discussion on this issue is expected to occur at the next JCM this fall. In addition, the Agreement on Scientific Cooperation between the US National Academy of Sciences and the USSR Academy of Sciences (AS) established a Joint Committee on Global Ecology in December 1988 to support related bilateral and multilateral efforts, particularly those carried out under the existing environmental agreement.

International Geosphere-Biosphere Program

Since 1985, there have been a number of international programs to assess the magnitude and timing of global climate change on environmental and societal systems. One such program is the International Geosphere-Biosphere Program (IGBP). Launched in 1986 by the ICSU, the IGBP's objective is to describe and understand the interactive physical, chemical, and biological processes regulating the total earth system and the manner in which anthropogenic activities are influencing the system. Implementation of the IGBP will require interdisciplinary international research on an unprecedented scale as well as a long-term political commitment to develop the scientific basis upon which policy decisions can be made.[42]

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[42]Committee on Global Change, Toward an Understanding of Global Change: Initial Priorities for US Contributions to the International Geosphere-Biosphere Program (Washington, D.C.: National Academy Press, 1988): 6-10.

There are five major areas in which the IGBP recommends further review: water-energy-vegetation interactions, fluxes of radiatively active trace gases and nutrients, biogeochemical dynamics in the ocean, earth system history and modeling, and human interactions with the global environment. Of these five, WG VIII has conducted, and currently engages in, research on trace gas fluxes, ocean dynamics, and paleoclimatology and climate modeling.

The objective of research on the exchange of radiatively active trace gases between the terrestrial biosphere and the atmosphere is to improve an understanding of the ecosystem processes that determine gas fluxes. This understanding is needed to construct models that can be used to predict how climate and land use change will alter emissions and absorption of radiatively active trace gases from the biosphere and, in turn, feed back to change climate further.

Two areas in which the IGBP recommends further investigation for trace gas fluxes are the Arctic and the tropics, which could play a significant role in global change.[43] WG VIII has played an integral role in Antarctic research since 1975, as discussed in previous chapters.

More recently, attention has shifted to the Arctic, and WG VIII recently conducted a joint experiment to study the relationship between stratospheric ozone and aerosols in that region. The Heiss Island Project, previously discussed, is one example of the shift in attention to the Arctic, as is the aerosol sampling campaign on Wrangel Island in the Chukchi Sea (see Figure 4.2). During April and May 1989, samples of soot aerosols were collected at Wrangel and compared with those from the Barrow GMCC Observatory in Alaska, where NOAA is continuously monitoring soot. At present, no one knows the rate at which soot is removed from the Arctic atmosphere. The Wrangel/Barrow pair is ideal since there is only open water between them. Thus, aerosols are lost only in the deposition process to the frozen Arctic ocean surface and could provide further answers for this potentially climate-sensitive area. In addition, black carbon is considered a radiatively important trace species (RITS) along with carbon dioxide, methane, freon, and others. Measurements of black carbon can thus be used to determine whether the "blackening" of the ice contributes to the greenhouse warming by the amount of sunlight coming down and being radiated back. During 1990, the US and USSR will continue to independently collect aerosol samples in Arctic regions. There is also the upcoming joint study of methane out-gassing from the Arctic

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[43]Ibid.

Figure 4.2 Location of aerosol sampling campaign at Wrangel Island, USSR (1989).

tundra and permafrost regions in Western Siberia discussed in Chapter 3.

Another area of importance in the IGBP is understanding and predicting the effects of climate change on ocean biogeochemical cycles and their corresponding feedback to climate. The major thrust of emphasis is a "global-scale assessment of the processes governing the rates of primary production and determining the fate of biogenic materials in the sea."[44] Within WG VIII, the research conducted between New York University and the State Hydrological Institute formed the basis for continuing joint investigation on the potential coupling of the greenhouse effect, carbon cycle, stratospheric ozone depletion, and marine primary productivity.

The role of sulfur gases emitted from the oceans, which may play a role in modifying the earth's climate, was studied in the Eastern Pacific in late May 1989. Sulfur gases rising from the ocean into the atmosphere are oxidized, and the resulting sulfate aerosol particles are believed to influence the reflectivity of clouds by increasing the population of cloud-condensation nuclei.

A third area in which WG VIII is particularly well suited to support the activities essential to the success of the IGBP is modeling global climate change and paleoclimate studies. One of the most productive programs in WG VIII has been in paleoclimatology. Since 1976, conferences or symposia have been conducted every other year (with the exception of 1984) to discuss US and USSR research on the climate of the Pleistocene and Holocene eras. WG VIII continues its emphasis in these areas as evidenced by the forthcoming Special Report, the 1989 joint Arctic study in Beringia, permafrost research, sampling loess fossil soils and pollen spectra, exchange of paleodata, and other activities concerned with paleoclimate study.

The Montreal Protocol and the IPCC

Two other international programs in which WG VIII directly or indirectly has made a contribution are the Montreal Protocol on Substances that Deplete the Ozone Layer and the Intergovernmental Panel on Climate Change (IPCC). On September 16, 1987, the Montreal Protocol was adopted by a conference convened by UNEP. The protocol entered into force on January 1, 1989, with ratification by 28 countries. This protocol essentially requires a freeze on a weighted basis at 1986 levels on production and consumption of CFC-11, -12, -113, -114, and

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[44]Ibid, p. 20.

-115, beginning mid-1989. This will be followed by phased reduction to 50 percent of 1986 levels by mid-1998. The production of halons 1211, 1301, and 2402 will be fixed at 1986 levels beginning in 1992.[45] Although the research activities conducted within WG VIII did not have any significant impact on this protocol, comparison of US and USSR theoretical models and observational data did contribute to a heightened Soviet understanding and sensitivity of the problem.

The IPCC

In 1988, the WMO and UNEP established the Intergovernmental Panel on Climate Change (IPCC) to address the issue of climate change; its environmental, economic, and social impacts; and possible national and international responses to such changes. The objectives of the IPCC are to: (1) assess the state of understanding of climate change and potential social, economic, and environmental impacts; and (2) develop an effective interface between science and policy makers. The IPCC working groups would not undertake scientific research themselves or duplicate existing scientific information-exchange mechanisms. Rather, they would provide an intergovernmental forum for developing consensus and proposing policy responses.

Consequently, the IPCC established three working groups on research, impacts, and policy responses.[46] Working Group 1, chaired by the United Kingdom, was authorized to review the state and knowledge of the science of climate and climate change, with special emphasis on global warming. Under the chairmanship of the USSR, Working Group 2 was delegated to review programs and conduct studies on the social and economic impacts of climate change. The US chairs Working Group 3, which was assigned the task of developing and evaluating possible policy responses by governments to delay, limit, or mitigate the impact of adverse climate change.

The USSR provides overall coordination in Working Group 2. However, USSR WG VIII Co-Chairman Mikhail Budyko and recently-departed US WG VIII Co-Chairman Alan Hecht, are steering committee chairmen in this IPCC Working Group as well. In

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[45]United Nations Environmental Program, Montreal Protocol on Substances that Deplete the Ozone Layer, Final Act, September 16, 1987.

[46]U.S. IPCC News, Number 1, March 1989, compiled and edited by the National Climate Program Office in cooperation with the Department of State.

addition, WG VIII American and Soviet scientists are individually involved in various portions of the IPCC science report. For example, research on possible future climate scenarios, including paleoclimatic reconstructions as analogs of future climates, is being assessed within WG VIII. US and USSR scientists have laid out a plan to collect and compile data to test reconstructions of past climates and to evaluate the usefulness of these reconstructions as an analog for the future. These analyses will be published in the WG VIII special joint US/USSR report.

The activities undertaken within WG VIII on climate change demonstrate the overlapping support given to other international activities which are concerned with this issue. As further research develops new insights into the role of climate, WG VIII will continue to play a contributing role in bilateral and multilateral research efforts.

Chapter 5

ANALYSIS

Working Group VIII has provided a framework for scientific cooperation on climate-related issues among scientists in the US and USSR for 15 years. The interaction between both countries has, in recent years, become increasingly less formal and more relaxed, but the goals and objectives of the program have always remained well defined. The activities implemented each year reflect an evolving and expanded understanding of the science of climate change.

5.1 PROSPECTS FOR THE FUTURE

WG VIII continues to develop new ideas and look for opportunities which will help the program become even more effective and productive. For instance, the formation of commercial joint ventures is not a normal activity for WG VIII. Nevertheless, this new direction is being used to solve the problem of supplying ozone-monitoring instrumentation to the USSR on a continuing basis and will allow USSR scientists to manufacture and use world-standard instrumentation. This project, to begin the joint manufacture of ozonesondes, was officially included in the 1989 WG VIII Protocol. Science Pump Corporation (Camden, NJ) and the Central Aerological Observatory (Moscow) have begun the process of establishing this joint venture, which will ensure the continuation of compatible US and Soviet observations of stratospheric ozone in the polar regions.

Changes within the USSR since 1985 and the introduction of "glasnost" have already improved many aspects of scientific collaboration between US and USSR participants. According to some of the US participants, particularly those involved in the pre-Gorbachev period, significant improvements since 1985 include:

(1) A much more relaxed and congenial atmosphere during the 1987 SAGA-II cruise compared with the earlier 1983 SAGA-I cruise.

(2) Soviet scientists no longer fear receiving mail and calls from colleagues outside the Soviet Union.

(3) There is a more cooperative spirit, and communication has improved. Earlier, lack of cooperation and knowledge among Soviet research teams made exchanges difficult.

(4) The ability of Soviet scientists to engage in meaningful and significant scientific contributions has increased enormously.

(5) There is more interest at all levels of Soviet society in man's impact on the environment.

(6) There are more young, active Soviet scientists travelling to the US.

(7) Soviet scientists go to great lengths to arrange cooperative activities and consider multiple sides of an issue.

(8) The increased presence of Soviet scientists at international scientific conferences is a positive signal.

The positive changes exhibited within the scientific community in the USSR are undoubtedly a reflection of the momentous political changes occurring there as well. An example of the shift in Soviet foreign policy with regard to US-Soviet scientific cooperation is the two major scientific agreements recently established: the US-USSR Space Agreement and the agreement between the US National Academy of Sciences and the USSR Academy of Sciences. Even more important for the future growth of WG VIII, however, is the serious attention the USSR has given to its own internal environmental degradation and its commitment to work with the US and other nations on climate-change issues, topics which were previously discussed.

Recent events in the US and USSR could very well place WG VIII in an even more pivotal position. With political attention increasingly turning to the issue of climate change and its implications, the Soviet Union indicated in 1988 the need for a separate agreement on cooperation in global climate change.[47] A new agreement would solidify an independent and expanded joint program under Goskomgidromet's responsibility (distinct from the environmental agreement now under Goskompriroda). Should the US not wish to pursue such an agreement, it is expected that joint research on global climate change will remain under the existing environmental agreement (and hence under Goskompriroda's control). However, according to Goskomgidromet, it "would still be responsible for executing this portion [WG VIII] of the

[47]Telegram from the American Embassy, Moscow, to the Secretary of State, August 5, 1988.

Agreement but may not be interested in or capable of supporting an expanded program."[48] This issue is still under discussion.

5.2 IS WG VIII A BENEFIT TO SCIENCE?

Global-scale environmental issues cannot be addressed by one nation or even by a small group of nations acting alone. Anticipating the consequences of climate change will take the effort of all nations working together to ensure that the international actions to limit and adapt to the changes in climate are taken on a sound basis. Since 1974, WG VIII has played a continuing role in this endeavor to develop observational data, computer models, and the understanding needed to anticipate the course of climate change. In particular, WG VIII has benefitted science in the following areas:

(1) WG VIII has had access to information and locations not previously available to US scientists, i.e., paleoclimate data from interior Eurasia and from the Siberian Arctic, and carbon dioxide research conducted in northern waters near Kamchatka. The acquisition of key data on the extent and timing of ice sheets at the last glacial maximum was central in developing a scientific understanding of the causes of long-term climate change, and the information was an important part of the CLIMAP (Climatic Long-range Investigation Mapping and Prediction project) publications on the last ice age.

(2) US and USSR scientists continue to have greater contact with each other. This contact will contribute to strengthening US-USSR cooperation by providing insight and ideas on Soviet thinking on particular issues, i.e., paleoclimatology as an analog to the future.

(3) Intercalibration and interpretation of USSR instruments and data have become easier and more readily available, thus increasing confidence in the quality of the data produced.

(4) The USSR has supplied a considerable amount of climatic data records, and they provide substantial logistical support for large-scale field experiments, i.e., the SAGA cruises, Heiss Island Project, desert aerosol experiment.

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[48]Ibid.

(5) WG VIII scientists have contributed to many international debates and assessments concerned with stratospheric ozone depletion and greenhouse warming, i.e., the Montreal Protocol, the IPCC, and the IGBP.

5.3 IS WG VIII A GOOD MODEL FOR FUTURE COLLABORATION OF SCIENCE AND TECHNOLOGY IN OTHER AREAS?

The recent space and ecology agreements between the US and USSR resulted not from one successful program but more from an awareness of the need to cooperate in other important areas of science and technology. As work progresses under these newly established agreements, their future expansion should be assessed carefully. A review of the aspects of WG VIII that have contributed to its effectiveness may be helpful in implementing the new agreements:

(1) WG VIII has always focused on the most significant scientific problems relating to climate change.

(2) WG VIII has linked US federal agencies, universities, and participants from the private sector with an equally diverse representation from USSR institutions.

(3) Over the 15 years of its history, WG VIII has maintained the continuity and momentum of its scientific focus despite fluctuations in the political climate between the US and USSR.

(4) The program has engendered an atmosphere of confidence and mutual trust among its members.

Perhaps the lessons learned within WG VIII can be applied with regard to scientific cooperation with China. As one leading Chinese physicist expressed, "It is absolutely essential for the United States to keep traffic and intercourse with China going as much as possible."[49] In this regard, Chinese and US scientists need to keep open channels of communication that are essentially apolitical, promoting the positive aspects of collaboration. In particular, programs should focus on areas that are known to be scientifically strong in China and capable of making significant contributions to the international community overall. It is prudent that scientists in both countries proceed with caution until a more conducive collaborative environment has been

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[49]Marjorie Sun, "Soul-Searching After China Crackdown," Science 245 (August 4, 1989): 461-2.

restored. The ties that have already been established, resulting in many years of successful research between US and Chinese scientists, must not be severed. The experience of WG VIII has shown that as time progresses, an increasingly effective collaborative relationship will emerge based on the mutual trust and dedication of far-sighted US and Chinese scientists.

5.4 RECOMMENDATIONS TO IMPROVE WG VIII'S EFFECTIVENESS

Communication between the US and USSR through traditional channels has always been problematic at best. Of all those surveyed, the predominant complaint by many American scientists was their inability to reach their Soviet colleagues in a reliable and timely manner. Most cables are sent between the JC executive secretaries and WG VIII coordinators, and the process is very slow and cumbersome. The USSR does not have adequate facsimile capabilities, although this service is gaining in popularity. Even so, it is very expensive for the USSR to use facsimile, and Soviet telephone lines are very noisy and in need of a major overhaul.

Express mail to the USSR is not really "express," usually reaching its destination up to ten days later, depending on where a letter is sent. In addition, not all "express" services have established routes to the USSR, and this creates additional uncertainty as to which service goes where. At present, many letters or small packages are "hand carried" into or out of the USSR by scientists during an exchange visit. Although not ideal, this method has been the most reliable.

Placing a telephone call is somewhat of a chore, too. There is an eight-hour time difference between Washington and Moscow, which means that a call usually must be placed before 8 a.m. (eastern time) to reach someone in their office. For those on the West Coast, placing a call to the USSR usually means getting up very early in the morning or staying up very late at night. There is also no guarantee that a line into the Soviet Union will even be available. Currently, there are approximately 25 lines available to the USSR through AT&T; and if they are all busy, only "emergency calls" are given priority.

Thus, it was evident that additional means of communication be established between US and USSR scientists. For this reason, in 1989, WG VIII began using electronic mail, or e-mail. It has the capability to permit around-the clock communication between parties in the US and USSR via a satellite circuit. It is also less expensive than communication by telex, fax, cable, express mail, or telephone. Electronic mail service is already being

used by business, scientific, and educational communities in the US and USSR. The new network links make it possible to send electronic mail, or instantly transfer software or technical information, between the two countries. It can also be tailored to fit almost any need, from translation services to a direct-digital private-line service which will support digital voice, facsimile, high-speed computer data, and graphics transmissions.[50]

Access to an electronic mail system is relatively easy for both US and USSR scientists, although some of the necessary computer equipment will be more readily available for US scientists than for those in the USSR. To come on line to an electronic mail system, a USSR scientist must acquire:

(1) An error-correcting modem (to optimize USSR telephone performance);

(2) Any kind of a computer, although a PC is fairly standard;

(3) Communications software that is compatible with the computer being used. A recent Soviet-developed software system called FAST supports both Cyrillic and Roman characters;[51]

(4) An ID from the Institute for Automated Systems that will connect the user to the USSR "gateway," the center where a user directly dials into the e-mail system from a remote terminal with a password;

(5) A password to access the e-mail system;

(6) A transformer (if a western-made PC or printer is used);

(7) Access to some printing device (provided the message needs to be printed).

Obviously, obtaining the appropriate computer system in the USSR is difficult, but they are moving quickly to fill the gap. Nonetheless, a temporary loan of computer equipment or even financial assistance should seriously be considered by all US

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[50]Telephone interview with Mr. Thomas Wainwright, San Francisco/Moscow Teleport, Inc., and Susan Kubany, Omnet Services, Boston, MA, June 8, 1989.

[51]Thomas Wainwright, ibid.

participants involved in WG VIII. Perhaps the federal agencies could pool their financial resources to cover the cost of the error-correcting modem for their Soviet colleagues, which at present can only be purchased in hard currency.

Other factors which should be considered include: (1) a locally based USSR office for providing immediate assistance to Soviet users; (2) the ability for Soviet users to pay for e-mail service in rubles; (3) on-line translation service which will allow US and USSR scientists to send messages to each other in their own languages; and (4) the capability to communicate while at remote locations, i.e., during oceanographic expeditions and campaigns such as those in the Arctic and Central Asia. Electronic mail will undoubtedly contribute significantly to WG VIII's overall effectiveness. Scientists in the two countries will be able to communicate quickly about new research interests, activity results, and publications.

Another frustrating aspect of WG VIII is the inadequate level of funding. This is not a new issue, and one which was broached as early as 1976 to NSF and in 1977 to EPA. For university participants, there is a need for a stable level of fiscal support at NSF to ensure the continued participation of interested and competent scientists. At present, the peer-reviewed procedure does not guarantee funding of joint US-USSR activity, despite a proposal receiving the highest-qualifying marks. Consideration should, therefore, be given to developing some satisfactory procedure for making funds available specifically to support activities associated with US-USSR bilateral agreements.

Similarly, for federal agencies wishing to participate, the present arrangement requires that each derive financial support for bilateral activities from other (budgeted) programs. This virtually ensures that joint studies will be relatively modest in scope. Much of WG VIII's activities are thus confined to visits and meetings of small groups of experts. As discussed previously, the largest percentage of activities are, indeed, the short- and long-term exchange visits of one or two participants. If it is the intent of the US government, and certainly the desire of the participating scientists, that substantial joint activities take place, then some special budget arrangement should be sought. Without a dependable level of support, project leaders are hesitant to undertake complex, yet potentially beneficial, projects.

In the final analysis, it is the individual US and USSR scientists themselves who really have made WG VIII the success it has been for the last 15 years. Some participants have come and gone while others surface as the needs of the program dictate.

Table 5.1 indicates the length of affiliation of the 44 US participants who responded to the survey. The largest percentage of participants in WG VIII are relative newcomers, averaging three years or less (47.5%). However, almost a third of the participants in this category were only involved in a "support" capacity aboard the first two SAGA cruises. In other words, at the end of the three-month expeditions, affiliation with WG VIII basically was terminated and only the "principal investigator" maintained his or her link with the program. In addition, some of the newcomers are participating in recently-established projects, such as the research conducted with New York University and the State Hydrological Institute, the field studies on Lake Baikal, and the desert aerosol campaign, which are expected to be long-term activities.

TABLE 5.1

LENGTH OF AFFILIATION OF US PARTICIPANTS IN WG VIII

	No. of Participants	Percentage of Total
3 years or less	19	47.5
3 - 6 years	3	7.5
6 - 9 years	7	17.5
9 - 12 years	6	15.0
12 - 15 years	5	12.5
	40	100.0

Note: Includes affiliation up to the present year, 1990. In addition, four participants did not indicate their length of affiliation in the program.

Nonetheless, many of the respondents took the time to suggest areas within the program which could stand some improvement, and these are listed below. Some have already been examined throughout this report, especially those which were mentioned frequently, i.e., the communication issue and inadequate funding and, therefore, are not included in the list. However, if WG VIII is to continue to evolve in order to address new scientific concerns, perhaps it would be useful for program

managers to seriously evaluate "problem" areas which may lead to the deterioration of, what has been up to now, a useful and successful program:

(1) Data exchange procedures need to be improved. Many US scientists are not "impressed" with mere promises of data exchange. This has had a particularly negative effect on participation in subsequent joint experiments, as was previously examined.

(2) Better continuity needs to be established after an experiment terminates. Accordingly, there should be increased support for post-experiment visits to facilitate data exchange and joint papers.

(3) Improve coordination of future experiments to allow sufficient time to obtain grant funding.

(4) Improve customs procedures for getting instrumentation into and out of the USSR. For the most part, samples taken during an experiment are not permitted to leave the USSR, thus impeding scientific study.

(5) Develop a newsletter for participants (in the US, in particular, but it certainly could include the USSR) keeping them abreast of WG VIII's activities.

(6) Establish some form of regular monitoring on the Eurasian continent where CO_2 and other trace gas samples are taken usually at a USSR site. This will complement other measurements elsewhere around the globe.

(7) Along this same line, develop a more continuous aerosol monitoring effort, either at Wrangel Island or at another similar location in the Soviet Arctic comparable to the GMCC station in Barrow, Alaska.

(8) Improve US interagency cooperation to carry out the expanding list of collaborative activities.

(9) Joint US/USSR satellite experiments flown on Soviet satellites should be expanded.

(10) Promote visits by Soviet scientists with durations of at least one year.

(11) Among US scientists, more emphasis should be placed on the value of literacy in foreign languages and international cooperation.

(12) Information about available data sets should be disseminated throughout the community along with information as to the appropriate channels through which requests should be made to access the data.

(13) Researchers who are willing to work with Soviet scientists should be encouraged to do so on topics that contribute to the program.

(14) There is a tremendous overlap in sea-ice research in both countries, and cooperation in this area should be encouraged as there is no shortage of suitable projects.

(15) Access to Soviet satellite and aircraft imagery in the Arctic with ancillary surface measurements would be useful for monitoring global climate change.

5.5 WORKING GROUP VIII IN PERSPECTIVE

Working Group VIII has provided a framework for scientific cooperation on climate-related issues among scientists in the US and USSR for 15 years. The interaction between both countries has, in recent years, become increasingly less formal and more relaxed, but the goals and objectives of the program have always remained well defined. The activities implemented each year reflect an evolving and expanded understanding of the science of climate change.

As noted previously, the expanding dialog that has developed between the US and Soviet scientific communities involved in WG VIII significantly enhances the US level of understanding on Soviet thinking in climate-related issues. It has provided access to information and locations previously unavailable to US scientists. Activities have become less difficult since 1985 in response to Gorbachev's policy of "openness:" US and USSR scientists continue to have greater contact with each other, data exchanges are becoming more frequent, and intercalibration and interpretation of Soviet instruments have become easier.

In general, the principle of mutual benefit and reciprocity has been applied in the exchange of scientific and technical information and capabilities. Despite the apparent deficiencies still evident in many Soviet laboratories, and the frustration created by insufficient communication channels or lack of Soviet data, many of the US scientists who were surveyed have indicated their satisfaction in participating in the program. In particular, it was noted that Soviet scientists were very

cooperative and enthusiastic in working with their US colleagues. Their hands-on assistance and immediate logistic and technical support were always forthcoming. Many US participants have developed and continue to maintain close and personal friendships with their Soviet colleagues, which contributes to WG VIII's effectiveness as well.

In addition, WG VIII weathered the US reductions in bilateral cultural and scientific exchanges in the 70s and early 80s, and a more positive atmosphere between the US and USSR has emerged since 1985. The 1987 summit was particularly encouraging for WG VIII because both Gorbachev and Reagan signaled for increased cooperation in environmental protection. In addition, policies within the US and USSR have focused more emphasis on global climate-change issues. Other members of the international community have also voiced their concern about the degradation of the environment,[52] and steps are being taken by all concerned nations to address these issues, i.e., the Montreal Protocol and the IPCC. The contributions by WG VIII have been, and will continue to play, a useful role in these international deliberations.

Looking ahead, the prospects for WG VIII appear promising. Given the implementation of a reliable and efficient communication system, many of the problems voiced by US participants should evaporate. Joint publications will become easier and more frequent. Data exchanges should also improve. In addition, WG VIII's first joint venture in manufacturing ozonesondes will provide the USSR with the capability of supplying a larger percentage of required equipment with less reliance on US assistance. Overall, the benefits to science are likely to increase as research conducted within WG VIII becomes even more productive, especially if the level of funding is increased to support US-USSR cooperative activities more effectively.

It is the hope that WG VIII will continue as a fertile source for innovative and challenging research by US and USSR scientists attempting to provide answers to global-scale environmental problems.

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[52]David Dickson, "Europe Recognizes the Ozone Threat," Science 243 (March 10, 1989): 1279. See also World Commission on Environment and Development, Our Common Future (Oxford: Oxford University Press, 1987).

APPENDIX A

Working Group VIII Questionnaire

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1. Please describe briefly the research project(s) in which you participated during your involvement with Working Group VIII, i.e. dates, location, significance of project, etc. Please be sure to include the name of your Soviet counterpart as well as other U.S. and Soviet members (and their affiliation) who participated in your project. If the Soviet institution is part of the Academy of Science, please indicate this as well as the region of affiliation, i.e., the Latvian Academy of Sciences, etc.

2. What institution(s) financed your project(s), i.e., NSF, NASA, NOAA, etc.? How much financial assistance were you given to conduct your research?

3. It has been said that one of the advantages of cooperation with the Soviet Union is access to their climatological data, without which it would be impossible to study global climate change. In general, do you agree with this statement? If so, what Soviet data have been most useful to your project?

4. In which areas do the Soviet scientists appear to excel? Where are they deficient?

5. What are some examples of areas in which you have been frustrated in cooperating with Soviet scientists? Please be specific, i.e., date(s) of visitation, institutions involved, etc.

6. Conversely, what are some examples in which you experienced significant achievements or satisfaction as a result of such cooperation?

7. If you have been involved in WG VIII for a number of years, you may have seen some areas in which significant improvements in cooperating with Soviet scientists have occurred, i.e. data exchange, access to Soviet laboratories, quality of work, attitude change, etc.? Please comment on these changes.

8. In general, have you found the exchanges to be fruitful or productive enough to justify your costs? If not, why? Do you see room for improvements?

9. Have the scientific results of your project contributed to any of the various international debates/assessments that are surfacing within recent years, i.e., the Montreal Protocol, the Intergovernmental Panel on Climate Change (IPCC), "trends" reports, etc.? If so, please indicate how your work became of interest and the significance of your research to the

debate/assessment. If not, is there growing public/government interest in the relationship between your research and climate change for future international debates/assessments? Please explain.

10. Has your project/experiment culminated in a jointly-published document? If so, what was the name of the journal in which it was published and date of publication? If publication is expected soon, please include the same information.

APPENDIX B

U.S. Scientists Who Responded to Survey

	Current Affiliation
James H. Butler	University of Colorado, Boulder
Eddy C. Carmack	Institute of Ocean Sciences, Sidney, British Columbia, Canada
Anthony D. Clarke	University of Hawaii, Honolulu
Dagmar Cronn	Washington State University, Pullman
John DeLuisi	NOAA/Environmental Research Lab, Boulder
Vernon Derr	NOAA/Environmental Research Lab, Boulder
James W. Elkins	NOAA/Environmental Research Lab, Boulder
Richard R. Fisher	NCAR/High Altitude Observatory
Richard Gammon	University of Washington, Seattle
James Gendron	NOAA/Pacific Marine Environmental Lab, Seattle
Dale A. Gillette	NOAA/Air Resources Lab, Boulder
Anthony D. A. Hansen	Lawrence Berkeley Laboratory, University of California--Berkeley
Robert C. Harriss	University of New Hampshire, Durham
Donald F. Heath	NASA/Goddard Space Flight Center, Greenbelt
John Imbrie	Brown University, Providence, RI
Norman Kjome	University of Wyoming, Laramie
Walter D. Komhyr	NOAA/Environmental Research Lab, Boulder
John E. Kutzbach	University of Wisconsin, Madison
Michael MacCracken	Lawrence Livermore National Laboratory, University of California--Livermore
Syukuro Manabe	NOAA/Geophysical Fluid Dynamics Laboratory, Princeton
John M. Miller	NOAA/Air Resources Lab, Silver Spring, MD
Frederick E. Nelson	Rutgers University, New Brunswick, NJ
Gerald R. North	Texas A & M University, College Station
Gilbert M. Peterson	University of Wisconsin, Madison
James Peterson	NOAA/Air Resources Laboratory, Boulder
Gerald L. Potter	Lawrence Livermore National Laboratory, University of California--Livermore
Patricia Quinn	NOAA/Environmental Research Lab, Boulder
Rei Rasmussen	Oregon Graduate Center, Beaverton
Alan Robock	University of Maryland, College Park
James M. Rosen	University of Wyoming, Laramie
Howard H. Sargent, III	NOAA/Space Environment Lab, Boulder
Michael E. Schlesinger	University of Illinois @ Urbana-Champaign
Lynne D. Talley	Scripps Institution of Oceanography, La Jolla, CA
Alan S. Thorndike	University of Puget Sound, Takoma, WA
Anandu D. Vernekar	University of Maryland, College Park
Tyler Volk	New York University, New York, NY
Wei-Chyung Wang	Atmospheric and Environmental Research, Inc., Cambridge, MA
Lee S. Waterman	NOAA/Environmental Research Lab, Boulder

Ray F. Weiss	Scripps Institute of Oceanography, La Jolla
Ronald M. Welch	South Dakota School of Mines and Technology, Rapid City
Richard T. Wetherald	NOAA/Geophysical Fluid Dynamics Laboratory, Princeton
John W. Winchester	Florida State University, Tallahassee
Gregory W. Withee	NOAA/National Oceanographic Data Center, Washington, D.C.
Donald J. Wuebbles	Lawrence Livermore National Laboratory, University of California--Livermore

APPENDIX C

Co-Chairmen and Executive Secretaries of the US-USSR Agreement on Protection of the Environment (Joint Committee)

	Co-Chairman of Joint Committee		Executive Secretary	
	US	USSR	US	USSR
1972	Russell Train	Yevgenii Fedorov	Jack Perry	Igor Chirchenko
1973				
1974		Yurii Izrael		Yurii Kazakov
1975				
1976				
1977	Douglas Costle		Pierre Shostal	
1978			Geoffrey Wolfe (9/78 - 9/79)	
1979			Linwood Starbird	
1980				
1981	Vacant		Gary Waxmonsky	
1982				
1983				
1984	William Ruckleshaus (7/84)			
1985	Lee Thomas			
1986				
1987			Amy Evans (Acting: 5/87 - 8/87)	
1988		Feodor Morgun	Sidney Smith (9/87)	Natasha Dobrovolskaia
1989	William Reilly	Vladimir Vorontsov	Gary Waxmonsky	

APPENDIX D

Working Group VIII Co-Chairmen and Executive Coordinators

	Co-Chairman of WG VIII		Executive Coordinator	
	US	USSR	US	USSR
1974	**Wilmot Hess** (NOAA/Environmental Research Laboratory)	**Yevgenii Borisenkov** (Main Geophysical Observatory)	**John Mirabito** (NOAA/Office of Programs & International Affairs)	**Igor Chirchenko** (Main Hydrometeorological Service)
1975	**Edward Epstein** (NOAA/Environmental Monitoring & Prediction)			
1977		**Yurii Sedunov** (Main Hydro Service)		
1980		**Victor Boldyrev** (State Committee for Hydrometeorology)		
1981	**Eugene Bierly** (National Science Foundation)		**Howard April** (NOAA/National Weather Service)	
1982	**Alan Hecht** (NOAA/National Climate Program Office)		**Martin Yerg** (NOAA/National Climate Program Office)	
1986		**Mikhail Budyko** (State Hydrological Institute)	**Robert Etkins** (NOAA/National Climate Program Office)	
1990	**Joseph Fletcher** (NOAA/Environmental Research Laboratory			

APPENDIX E

Working Group VIII Project Leaders

		Project 11	Project 12	Project 13	Project 14	Project 15
1974	(US)	Joe Smagorinsky	Lester Machta	John Wilcox		
	(USSR)	Mikhail Budyko	Igor Karol	Evald Mustel		
1975						
1976						
1977						
1978	(US)	Larry Gates				
1979	(US)		Kirby Hanson	Jack Eddy		
1980						
1981	(US)		John Miller			
1982						
1983						
1984						
1985	(US)	Mike MacCracken				
1986	(US)			David Rust/	Roy Jenne	
	(USSR)			Bob Schiffer	Vladimir Smirnov	
1987	(USSR)			Georgii Golitsyn		
1988						
1989	(USSR)				Rudolf Reitenbakh	
1990	(US)					Bob Watson
	(USSR)					Vyacheslav Khattatov

APPENDIX F

US Academic Institutions Participating in the Activities of WG VIII

Alaska, University of
Arizona State University
Arizona, University of
Aspen Institute of Humanistic Studies
Brown University
California, University of (Berkeley)
Colorado State University
Colorado, University of
Columbia University (Lamont Doherty Geological Observatory)
Florida State University
Florida, University of
Georgia Institute of Technology
Harvard University
Hawaii, University of
Illinois, University of (Urbana-Champaign)
Johns Hopkins University
Maryland, University of
Massachusetts Institute of Technology
Massachusetts, University of
Miami, University of
Michigan, University of
Minnesota, University of
Missouri, University of
New York University
Ohio State University
Oklahoma, University of
Oregon Graduate Center
Oregon State University
Oregon, University of
Pennsylvania State University
Rhode Island, University of
Rutgers University
Scripps Institute of Oceanography
Stanford University
State University of New York (Stony Brook)
Utah, University of
Virginia, University of
Washington State University
Washington, University of
Wisconsin, University of
Wyoming, University of

US Government Laboratories Participating in the Activities of WG VIII

Air Resources Laboratory, NOAA
Assessment and Information Services Center, NOAA
Climate Analysis Center, NOAA
Climate Impact Assessment Project, DOT
Environmental Protection Agency
Environmental Research Laboratories, NOAA
Geophysical Fluid Dynamics Laboratory, NOAA
Global Environmental Research Program, NASA
Global Monitoring for Climatic Change, NOAA
Goddard Institute for Space Studies, NASA
Goddard Space Flight Center, NASA
Langley Research Center, NASA
Lawrence Livermore National Laboratory, DOE
National Climate Data Center, NOAA
National Climate Program Office, NOAA
National Environmental Satellite, Data, and Information Services, NOAA
National Geophysical and Solar-Terrestrial Data Center, NOAA
National Institute of Standards and Technology, DOC
National Science Foundation
NOAA Baseline Station, Mauna Loa, Hawaii
Pacific Marine Environmental Laboratory, NOAA
Space Environment Laboratory, NOAA
U.S. Geological Survey, DOI
Wallops Flight Center, NASA

Non-Governmental Laboratories Participating in the Activities of WG VIII

Atmospheric and Environmental Research, Inc.
High Altitude Observatory, National Center for Atmospheric Research
National Academy of Sciences
National Center for Atmospheric Research
Science Pump Corporation

USSR Institutions Participating in the Activities of WG VIII

INSTITUTES OF GOSKOMGIDROMET:

All-Union Research Institute of Hydrometeorological Information, Moscow
Arctic and Antarctic Research Institute, Leningrad
Central Aerological Observatory, Moscow
Central Asia Regional Research Institute, Tashkent
Far East Institute of Hydrometeorology, Vladivostok
Geophysical Society, Leningrad
Hydrometeorological Center, Moscow and Tashkent
Hydrometeorological Institute, Tbilisi
Institute of Applied Geophysics, Moscow
Institute of Experimental Meteorology, Moscow
Laboratory for Monitoring the Natural Environment and Climate, Moscow
Main Astronomical Observatory, Leningrad
State Hydrological Institute, Leningrad

INSTITUTES OF THE ACADEMY OF SCIENCES OF THE USSR:

Astronomical Council of the USSR, Moscow
Botanical Garden, Moscow
Botanical Institute, Leningrad
Computer Center, Moscow and Siberian Branch (Novosibirsk)
Crimean Astrophysical Observatory, Yalta
Department of Numerical Mathematics, Moscow
Division of Computational Mathematics, Moscow
Institute of Atmospheric Optics, Siberian Branch
Institute of Atmospheric Physics, Moscow and Siberian Branch
Institute of Geography, Moscow and Azerbaijan
Institute of Limnology, Leningrad
Institute of Oceanology, Moscow and Leningrad
Institute of Physical Chemistry, Moscow
Institute of Plant Physiology, Moscow
Main Astronomical Observatory, Leningrad
Mountain Astronomical Observatory, Kislavodsk
North-East Interdisciplinary Scientific Research Institute,Magadan
Pacific Geographic Institute, Vladivostok
Siberian Institute of Terrestrial Magnetism and Radiowave Propagation, Moscow

OTHER ACADEMY INSTITUTES:

Byelorussian Academy of Sciences, Minsk
Institute of Botany, Lithuanian Academy of Sciences (LAS), Vilnius
Institute of Experimental Meteorology, Kazakh SSR Academy of Sciences
Institute of Physics (LAS), Vilnius
Institute of Plant Physiology, Tadjik Academy of Sciences (TAS), Dushanbe
Presidium of the Estonian SSR Academy of Sciences (EAS), Tallin
Umarov Physical-Technical Institute (TAS), Dushanbe
Uzbek SSR Academy of Sciences (UAS), Tashkent

ACADEMIC INSTITUTIONS:

Leningrad State University
Moscow State University

APPENDIX G

Working Group VIII Symposia, Workshops, and Significant Meetings

Date	Title	Purpose and/or outcome
1975	Meeting on atmospheric optics and aerosols (Leningrad; June 23-25, 1975)	Indicated that monitoring of appropriate optical and physical/chemical properties of aerosols would be required to understand their role in climate change due to either natural or man-made sources.
1976	The First Conference on Climates of the Pleistocene and Holocene Epochs (Moscow; November 16-25, 1976)	To discuss the results of Soviet research dealing with the analysis of changes in nature during the Holocene period.
	Joint meeting of WG I and WG VIII on man's activities affecting stratospheric ozone (Leningrad; June 21 - July 2, 1976)	To discuss the effects of various pollutants on the stratosphere and techniques needed to measure minor constituents in the stratosphere from both the earth's surface and from satellites.
1977	Symposium on the structure of of the present climate and its variability (Leningrad; 20-29, 1977)	Recommended further cooperative study in climate modeling.
1978	The Second Conference on the Climates of the Pleistocene and Holocene Epochs (Palisades, NY; June 18-27, 1978)	To discuss new data on the paleogeography of the US and USSR and the Atlantic Ocean during the upper Pleistocene and Holocene.
	Symposium on the effects of changes in atmospheric carbon dioxide (Dushanbe; October 12-20, 1978)	To discuss the global carbon cycle, carbon dioxide monitoring, effects of carbon dioxide on climate and plant productivity.

Date	Title	Purpose and/or outcome
	Meeting on climate and solar variability (Crimea; September 13-23, 1978)	To discuss problems of studying physical mechanisms of solar-terrestrial relationships, experimental validations, changes in large-scale circulation processes as well as large-scale anomalies of weather and climate (drought) associated with solar activity.
1979	Symposium on climate modeling, climate change, and statistical processing of climatic data (Tbilisi; October 15-22, 1979)	Emphasized need for further studies of model sensitivity they can be usefully applied to questions of climatic change as well as further diagnostic and statistical studies of both empirical and model-simulated data to foretell a change in modern climate on a global scale.
1980	Third Conference on the Climates of the Pleistocene and Holocene Epochs (Khabarovsk, Irkutsk, and Yakutsk; July 17-25, 1980)	Continued discussions on the reconstruction and modeling of the climate in the Northern Hemisphere during the late Pleistocene and Holocene eras.
1981	Workshop on the problem of atmospheric carbon dioxide and climate (Leningrad; June 15-19, 1981)	To discuss the studies of the global carbon cycle, forecasts of future carbon dioxide buildup, empirical research of modern climate changes, carbon dioxide effect on climate and paleoclimate reconstructions, problems of climate modeling, and presentations of numerical estimates of the effect of changing carbon dioxide concentration on climate.
	Symposium on Climatic Impacts of Solar Activity (Vilnius; May 25 - June 3, 1981)	To discuss the physical mechanisms involved in possible solar effects on climate; experimental and theoretical studies of changes in the solar constant and spectral solar radiation; and numerical modeling of atmospheric responses including photochemical changes.
1982	Fourth Conference on the Climates of the Pleistocene and Holocene Epochs (Moscow; July 28 - August 7, 1982)	Convened to coincide with the XI Congress of the International Union for Quaternary Research (INQUA), where results of US/USSR joint research was presented.

Date	Title	Purpose and/or outcome
1983	Meeting on "The Impact of Anthropogenic Factors on Modern Climate" (Leningrad; July 3 - 9, 1983)	To discuss modeling the climate's sensitivity to carbon dioxide changes; carbon dioxide and modern climate change; the use of paleoclimate evidence in studying anthropogenic effects on climate; and other factors causing modern climatic changes.
1984	Symposium on "Studying Atmospheric Trace Gas Components Affecting Climate" (Vilnius; August 27 - September 1, 1984)	To discuss new results of measurements of atmospheric trace gases, in particular, the distribution of such gases and their content over the Pacific Ocean as a result of the first Soviet-American Gas Aerosol (SAGA) expedition in 1983. In addition, the importance of systematic global monitoring of atmospheric trace gases at station networks and from mobile platforms was emphasized for estimating the extent of anthropogenic effects on atmospheric trace gases content and climatic characteristics as well as for more accurate information on trace gas atmospheric cycles.
1986	Meeting on "Causes of Recent Climate Change" (Leningrad; July 20-26, 1986)	To discuss modeling and empirical studies concerning the past and potential climatic effects of increasing carbon dioxide and trace gas concentrations/variations in atmospheric aerosol loading, which occurs as a result of volcanic and other influences.
1987	Meeting on the stratospheric ozone layer (Moscow; February 4-6, 1987)	To discuss measurement trends of ozone and other related trace gases, photochemical models, theoretical estimates of trends, and some problems of monitoring ozone. Particular emphasis was placed on the so-called "ozone hole" over Antarctica, which appears during the Austral Spring.
	Meeting on Arctic aerosols (Leningrad; September 21-25, 1987)	To discuss observational data on pollution in the Arctic, measurement programs and techniques, sources and transport of pollution, and climatic effects arising because of radiational, nucleational, and depositional processes. Other topics included the peculiarities of Arctic meteorology and optical characteristics of the Arctic atmosphere.

Date	Title	Purpose and/or outcome
	Symposium on "Solar Variability and Climate" (Yalta; November 15-20, 1987)	To discuss solar influence on climate, in particular, the variability of the sun and how this influences climate.
	Seminar on "Reconstruction of Paleoclimates and Natural Environmental Conditions" (Moscow; August 31 - September 5, 1987)	To plan a program to model and document the climate changes that have taken place over the past 25,000 years and to provide wider use of paleoclimate materials for projecting future climatic conditions.
1988	Workshop on Paleoclimate Reconstruction and Modeling (Madision, WI; September 13-15, 1988)	To discuss usefulness of paleoclimate models and reconstructions as analogs for future climate change due to greenhouse warming and as a means of assessing the accuracy of climate models.
1989	Workshop on Greenhouse-Gas-Induced Climatic Change: A Critical Appraisal of Simulations and Observations (Amherst, MA; May 8-12, 1989)	To discuss the reduction of uncertainties about the magnitude, timing, and regional details of future climatic changes as projected by climate models.
	Symposium on "Aerosols and Their Influence on Climate" (Obninsk; August 26 - September 1, 1989)	To discuss aerosols (marine, desert, volcanic and anthropogenic) and their sources, physical properties, methods of measurement, radiative effects on remote sensing and clouds. Aerosol-climate modeling was also a topic of discussion and included heirarchy of models, results of model calculation, methods of introducing aerosol radiative effects into models, model weaknesses, and urban effects of aerosols.
	Meeting on "Diagnosis and Forecasting of Short-Term Climate Variations on Time Scales of Months, Seasons, and Years" (Moscow; November 12-18, 1989)	To discuss the spatial inhomogeneity of climate variations on the season-yearly-decadal time scale and the impact on social, economic, and political interests. It was suggested that a joint monograph be developed to describe, compare, and combine significant research findings on this subject.

Date	Title	Purpose and/or outcome
	Meeting on climate-change data sets (Obninsk; September 3-9, 1989)	To prepare basic data sets for the detection of climate change.

APPENDIX H

Working Group VIII Joint Publications

1976 "An Analysis of GATE Aircraft Pyrgeometer Instrumentation," Proceedings of IUGG, IAMAP Symposium on Radiation, August 16-29, 1976, Garmisch-Partenkirchen, FRG.

1977 "An Analysis of GATE Aircraft Pyrgeometer Instrumentation," jointly published in the Bulletin of the American Meteorological Society 58, pp. 950-955.

1978 The Atmospheric Aerosol and its Effect on Radiation Transfer, joint monograph published by the Hydrometeorological Printing House, Leningrad.

1979 Proceedings of the Symposium on the Effects of Changes in Atmospheric Carbon Dioxide (October 12-20, 1978, in Dushanbe) published by the Hydrometeorological Printing House, Leningrad.

"Cooperative USA-USSR Atmospheric Transparency Measurements," jointly published in the September 1979 issue of the Bulletin of the American Meteorological Society.

"The Moisture Content of the Continents and the Intensity of Summer Monsoon Circulation," jointly published in Meteorologiya i Gidrologiya 11 (1979).

"Calculations of Free Atmospheric Shortwave Spectral Characteristics Over the Desert," jointly published in Tellus 31 (1979).

1980 "Cooperative Measurements of Spectral Transparency of the Atmosphere with Soviet and American Instruments," published in transactions of the Main Geophysical Observatory, No. 445 (1980).

1981 "The Effect of a Geographical Cloud Distribution on Climate: A Numerical Experiment with an Atmospheric General Circulation Model," jointly published in the Journal of Geophysical Research 86 (20 December 1981).

"Determination of Vertical Profiles of Aerosol Size Spectra from Aircraft Radiative Flux Measurements: Part I. Retrieval of Spherical Particle Size Distribution," jointly published in Journal of Geophysical Research 86 (1981).

"Determination of Vertical Profiles of Aerosol Size Spectra from Aircraft Radiative Flux Measurements: Part II. The Effect of Particle Non-Sphericity," jointly published in the Journal of Geophysical Research 86 (1981).

1982 Proceedings of the Symposium on Climatic Impact of Solar Activity (May 25 - June 3, 1981, Vilnius), published by the Hydrometeorological Printing House, Leningrad.

1983 Late Quarternary Environments of the United States and the Soviet Union, three-volume joint monograph published by the University of Minnesota and the Institute of Geography, USSR Academy of Sciences.

"The Solar Corona on 31 July 1981," jointly published in Solar Physics 83 (1983).

US/USSR Agreement on Cooperation in the Field of Environmental Protection, Working Group VIII on the Influences of Environmental Changes on Climate, Soviet-American Gas and Aerosol: Pacific Experiment (SAGA), preliminary report of joint cruise aboard the Soviet research vessel, Akademik Korolev, in the Pacific Ocean, December 1983.

"Abastumani Forest Aerosol Experiment - 1979: Comparison to Other Non-Urban Halocarbons and Nitrous Oxide Measurements," jointly published in Environmental Science and Technology 17, pp. 383-388.

1984 "Combined Effects of Earth's Orbit Perturbations and Solar Activity on Terrestrial Insolation: I. Sample Days and Annual Mean Values," jointly published in Journal of the Atmospheric Sciences.

1985 "Soviet-American Gas/Aerosol Experiment in the Pacific Ocean (SAGATEX-83)," joint publication in the Soviet journal Meteorologiya i Gidrologiya 1 (1985).

1987 Proceedings of the Symposium on Causes of Recent Climate Change (July 20-26, 1986, in Leningrad) published in the March 1987 issue of Bulletin of the American Meteorological Society and in the January 1987 Soviet issue of Meteorologiya i Gidrologiya.

US/USSR Agreement on Cooperation in the Field of Environmental Protection, Working Group VIII on the Influences of Environmental Changes on Climate, Soviet-American Gas & Aerosol Experiment (SAGA-2), preliminary report of joint cruise aboard the Soviet research vessel, Akademik Korolev, July 1987.

1988 "Trace Gases in the Atmosphere Over the Ocean," joint publication in the Soviet journal Physics of the Atmosphere and Ocean 24 (August 1988), pp. 835-843.

"Joint Soviet-American Research on the Global Distribution in the Atmosphere of Trace Gases Which Can Influence Climate," joint publication of proceedings of the Fifth Soviet-American Symposium held in Washington, D.C., December 1986, in Comprehensive Analysis of the Environment by Goskomgidromet.

1989 "US/USSR Monograph on Aerosols and Climate," joint publication by NOAA's Environmental Research Laboratories, Boulder, CO, June 1989.

"ECC Ozonesonde Observations at Mirny, Antarctica, During 1988," NOAA Data Report ERL ARL-19, Silver Spring, MD, September 1989.

"Changing Composition of the Troposphere: A Chemical and Mineralogical Investigation of Tropospheric Aerosols During the US-USSR DUNE Experiment in Dushanbe, Tadzhik SSR," WMO Special Environmental Report N17, Sofia, October 1989.

1990 "Prospects for Future Climate: A Special U.S./U.S.S.R. Report on Climate and Climate Change," a joint report called for by President Reagan and General Secretary Gorbachev in the joint communique issued at the conclusion of their summit meeting in December 1987.

APPENDIX I

List of Datasets the US Received from the USSR.

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1. Rawinsonde data for six USSR stations for ten years 1961-70 (2 tapes). IBM VB blocking, EBCDIC characters, maximum block size 1704 bytes. Received April 1986.

2. Satellite data on the total cloud amount for the northern and southern hemisphere, 5°x5° grid, 1976-85 (2 tapes). Received January 1987.

3. Satellite data on the total cloud amount for the northern and southern hemisphere, 5°x10° grid, 1966-85 (2 tapes). Received January 1987.

4. Daily data on surface pressure for the northern hemisphere, 5°x10° grid, 1880-1979 (4 tapes). Received October 1984 and again on January 1987.

5. Daily data on height and temperature fields in the free atmosphere at standard pressure surfaces for the northern hemisphere, 5°x10° grid, for approximately 1948-85. Levels: sea level pressure to 10 mb. Variable starting dates. No temps before 1969. Ten tapes received January 1987, seven received October 1987.

   This dataset was only prepared through 1985, then objective analyses began. Data received October 1988 to add missing grids (1 tape).

6. Monthly analyzed temperature data for the northern hemisphere, 5°x10° grid, 1891-1986 (1 tape). Received September 1987.

7. Monthly analyzed anomalies of the precipitation (in % of the norm) for the northern hemisphere, 2.5° grid, 1891-1960 (1 tape). Received September 1987.

8. Daily and monthly atmospheric circulation indices, location, and intensity of eight atmospheric activity centers for 1891-1986 in the first natural synoptic region of the northern hemisphere (1 tape). Received September 1987.

9. Selected marine meteorological data on world oceans for approximately 1900-1980 in binary coded format (1 test tape). Received September 1987.

10. Individual marine ship observations for the North Atlantic, mostly USSR ships, mostly 1957-87 with a total of 5,055,054 observations (20 tapes). Received January-March 1989.

In summary, the USSR provided tapes to the USA as follows:

* 25 tapes with data were sent to the US during December 1986 - September 1987

* 21 tapes with data for two datasets were sent to the US during October 1988 - April 1989

APPENDIX J

Data sent from the US to the USSR.

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1. National Meteorological Center (NMC) octagonal analysis grids for 1973-78; twice a day; sea level pressure and levels 1000 mb, 850 mb to 10 mb; height and temperature; winds 1000-100 mb (8 tapes, 6250 bpi sent to ASDNM in Moscow; they will provide copies for the World Data Center [WDC]-B).

2. NMC global analyses, surface to 50 mb, each 12 hours for 1 January 1984 through 27 May 1984; grid is 2.5° lat-longitude (3 tapes, 6250 bpi, sent to ASDNM, Moscow).

3. World monthly surface data; updated through 1985 (3 tapes hand carried to Leningrad, 1986.

4. Monthly sea surface temperature analyzed from the Climate Analysis Center (CAC), each year-month, for January 1970 through September 1986 (1 tape sent to ASDNM).

5. Rasmusson-Carpenter data set: monthly sea surface temperature data, Pacific Ocean, 1946-76, 30° North - 30° South, 2° lat-longitude squares. See Monthly Weather Review, May 1982 (2 tapes, 6250 bpi, sent to ASDNM).

6. COAD (Consolidated Ocean Atmospheric Dataset) ship statistics (each year/month) for 2° lat-longitude squares, 1854-1979. Group files 3 and 4 (sent to ASDNM).

   Group 3: Sea surface temperature, air temperature, specific humidity, relative humidity (2 tapes, 6250 bpi)

   Group 4: Scalar wind speed, eastward wind component, northward wind component, sea level pressure (2 tapes, 6250 bpi)

7. An update to the monthly upper air data tape for the world. This tape has data for 1983-1985. This complete dataset is collected and published by WDC-A (in Asheville). Data starts about 1950 (sent September 1987).

8. Climate data for the maximum of the last ice age (CLIMAP project) on a 2° grid with modern data for comparison. Includes temperature, elevation, soil type, vegetation, glacial ice, etc. (1 tape, sent September 1987).

9. Winds at all available levels, 1000-100 mb, year/month, September 1963 -December 1984 (1 tape, sent September 1987).

10. Monthly and annual CO_2 data, 1958 through 1986, sent from the DOE CO_2 Information Center to the State Hydrological Institute, Leningrad, in October 1987 (small dataset).

11. Monthly global ocean wind stress components (1 tape taken to the USSR, August 1988).

12. Monthly data for 1,219 US stations sent to the USSR from the DOE CO_2 Information Center (6 tapes to WDC-B and to the State Hydrological Institute, February 1989).

13. Daily US rawinsonde data sent to WDC-B; 17 stations for 1961-78 (17 tapes sent from the National Climate Data Center (NCDC), Asheville, March 1989).

14. COAD ship statistics (for each year/month) for 2° lat-longitude squares; world ocean; all five group files 1854 - 1979 (30 tapes sent to WDC-B April 1989).

In summary, the US side provided tapes to the USSR as follows:

* 25 tapes sent during the period November 1986 - September 1987.

* 54 tapes sent during October 87 - April 1989 (plus six more tapes of identical data sent to Leningrad.

GLOSSARY

aerosol - a system of liquid or solid particles colloidally dispersed in a gas. Haze, most smokes, and some fogs and clouds (e.g., polar stratospheric clouds) may thus be regarded as aerosols.

Antarctic ozone hole - a substantial reduction below the naturally occurring concentration of ozone over Antarctica.

chlorofluorocarbons - the primary CFCs affecting ozone concentrations are CFC-11 (trichlorofluoromethane) and CFC-12 (dichlorodifluoromethane).

climate model - a mathematical simulation of the physical laws governing the behavior of the climate system. Two basic types: (1) static, in which atmospheric motions are neglected or are represented with a simple parameterization scheme such as diffusion, and (2) dynamic, in which atmospheric motions are explicitly represented. The latter category includes general circulation models (GCMs).

coronagraph - an instrument for photographing the corona and prominence of the sun at times other than at solar eclipse.

Dobson spectrophotometer - a photoelectric spectrophotometer that is used in the determination of the ozone content of the atmosphere. The instrument compares the solar energy at two wavelengths in the absorption band of ozone by permitting the radiation of each to fall alternately upon a photo cell. The stronger radiation is then attenuated by an optical wedge until the photoelectric system of the photometer indicates that equality of radiation exists. In this manner, the ratio of the radiation intensity is obtained. The ozone content of the atmosphere is computed from this value.

Dobson Unit - a measure of total column atmospheric ozone. If brought to 1 atmosphere (1013.2 mb) of atmospheric pressure, 100 DU of pure ozone would measure 1 mm thick. Typical total column atmospheric ozone averages from 150-400 DU.

greenhouse gases - trace gases in the atmosphere that are strongly absorbent in parts of the infrared wavelength spectrum. These include carbon dioxide, methane, nitrous oxide, and some of the chlorofluorocarbons.

hydrocast - the process of measuring the salinity, temperature, and pressure of a column of water in order to determine the density of the water at a point in the column. Depending on how elaborate the instrument is when dropped into the ocean, chemical measurements and sound velocity can be taken.

lidar - an acronym for li(ght) (ra)dar, a meteorological instrument using transmitted and reflected laser light for detecting atmospheric particles, such as pollutants, to determine their elevation, concentration, size, characteristics, etc.

ozonesonde - an instrument that measures the vertical profile of ozone concentration in the atmosphere.

paleolimnology - the study of past life and phenomena of lakes, ponds, and streams

palynology - the study of spores and pollen.

polar vortex - the large-scale cyclonic circulation in the middle and upper troposphere centered generally in the polar region of the Northern Hemisphere, but there is also one in the Southern Hemisphere.

radiometric - a measurement of radiant energy especially in that portion of the total electromagnetic spectrum lying in and adjacent to the visible region.

radiosonde - an instrument system carried aloft into the atmosphere by balloons; it measures atmospheric pressure, temperature, and humidity, and relays this information to a receiver at the launch site.

solar constant - the rate at which solar radiation is received outside the earth's atmosphere on a surface normal to the incident radiation and at the earth's mean distance from the sun.

solar corona - the outer envelope of the sun's atmosphere observed at the time of a solar eclipse or with a coronagraph.

stratosphere - that portion of the atmosphere between the tropopause (at 8- to 18-km elevation, depending on latitude and season) and the stratopause (approximately 50 km).

Umkehr method - a method using ground-based Dobson instruments that measure ozone concentrations in atmospheric layers.

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