Physics Department
Lawrence Livermore National Laboratory

UCRL--51444-88/89

DE91 001057

Atmospheric *and* Geophysical Sciences Division

Program Report 1988-1989

June 1990

UCRL-51444-88/89
Distribution Category UC-403

Available from
National Technical Services
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
A05, microfiche A01

Dedication

Kendall R. Peterson
1929–1988

On December 4, 1988, Ken Peterson died suddenly while "tuning up" the bicycle he rode to work every day. Ken joined Lawrence Livermore National Laboratory (LLNL) as an atmospheric physicist in 1969, after working for the National Oceanic and Atmospheric Administration (NOAA) (formerly the U.S. Weather Bureau) for 15 years.

Throughout his scientific career, Ken was primarily interested in the transport, diffusion, and deposition of radioactivity and other pollutants on scales from hundreds of meters to global. His studies focused on the atmospheric nuclear weapons tests in the Pacific in the 1950s and the crater tests conducted at the Nevada Test Site in the 1960s as part of the Atomic Energy Commission's Plowshare Program. Ken was still working to refine this work at the time of his death. Working through the U.S. Department of Energy, Atmospheric Release Advisory Capability (ARAC) operated by LLNL, Ken was the primary person responsible for developing guidance for the Federal Aviation Administration regarding potential radiation doses to passengers and crew on aircraft flying near debris clouds produced by the Chinese atmospheric nuclear weapon tests conducted in the 1970s. During the accident at the TMI-2 nuclear reactor in 1979 and the purge of ^{85}Kr from the containment vessel in 1980, Ken's extensive experience in dealing with atmospheric dispersion processes played a key role in providing guidance to on-scene emergency response managers. He also played a major role for ARAC in developing estimates of the consequences of the U.S.S.R. Chernobyl nuclear reactor accident as the radioactive cloud was approaching the U.S. At the time of his death, Ken was working on developing models for estimating the internal radiative dose from nuclear war fallout.

In addition to his scientific expertise, Ken was a good friend to many of his colleagues and was always willing to help in every way he could. He was an excellent writer and reviewer, and many of his colleagues called on him to help improve their draft articles. In recognition of his writing skills, Ken received the "Distinguished Authorship Award" in 1969 from the Environmental Science Services Administration, the predecessor to NOAA.

Ken has been and will continue to be missed by his colleagues, both as a scientist and as a good friend.

CONTENTS

Program Report for 1988 and 1989 Atmospheric and Geophysical Sciences Division of the Physics Department

Abstract

In 1990, the Atmospheric and Geophysical Sciences Division begins its 17th year as a division. As the Division has grown over the years, its modeling capabilities have expanded to include a broad range of time and space scales ranging from hours to decades and from local to global. Our modeling is now reaching out from its atmospheric focus to treat linkages with the oceans and the land. In this report, which is intended to serve as a complement to the May–June 1990 combined issue of *Energy and Technology Review** that focuses on atmospheric sciences research, we describe the Division's goal and organizational structure. We also provide tables and appendices describing the Division's budget, personnel, models, and publications.

Introduction

The goal of the Atmospheric and Geophysical Sciences Division (G-Division) of the Physics Department at Lawrence Livermore National Laboratory (LLNL) is to contribute to advancing and improving the understanding and resolution of atmospheric and geophysical science issues of broad national and international significance. Our role includes the development, application, and interpretation of results from carefully formulated and verified numerical models of the atmosphere-geosphere system. We study the effects of energy- and defense-related emissions on the environment and apply state-of-the-art emergency response models to the consequence assessment and mitigation of high-impact, technological accidents involving atmospheric releases of nuclear or toxic materials. Our research efforts are primarily focused (1) on studying the perturbing effects of carbon dioxide, chlorofluorocarbons and other trace gases, and aerosol emissions on climate and long-term atmospheric composition and (2) on exploring the role of the atmosphere-geosphere system in dispersing, transforming, and depositing radionuclides, particles, trace gases, and toxic and heavier-than-air gases. To pursue this research and meet our Division goal, we combine a highly experienced and diversified professional staff (often involving collaborative efforts with university students and scientists), a broad range of atmospheric models covering scales from microphysical to global, and participation in field programs and exercises to aid in model verification.

The breadth and strength of our program continues to grow. G-Division's programs now involve about 90 scientists, engineers, and technical and supporting staff (see Appendix A). In addition, we work with an extended family of researchers from universities, other laboratories, and private organizations who enhance the quality and scope of our research (see Appendix B for a listing of collaborative activities).

* *Energy and Technology Review*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52000-90-5/6 (May–June 1990).

Table 1. **FY 1989 G-Division Budget by Sponsor.**

Sponsor Organization	Funding[a] (K$)	Percentage (%)
DOE		
Energy Research (ER)	$6,117	43.0
Defense Programs (DP)	2,777	19.5
Naval Reactors (NR)	247	1.7
Environmental Safety and Health (EH)	245	1.7
Policy, Planning, and Analysis (PE)	150	1.1
Other	211	1.5
Non-DOE Federal		
U.S. Department of Defense (DOD)	2,723	19.2
National Aeronautics and Space Administration (NASA)	800	5.6
Environmental Protection Agency (EPA)	160	1.1
National Oceanic and Atmospheric Administration (NOAA)	20	0.1
Nuclear Regulatory Commission (NRC)	15	0.1
LLNL		
Institutional R&D Program	250	1.8
LLNL Physics Department/Weapons Supporting Research	125	0.9
Other Departments	194	1.4
Nongovernment Organizations	184	1.3
TOTAL	$14,218	100.0

[a] Excludes equipment funding.

G-Division's activities range from research-oriented efforts involving the development of new, more comprehensive process models of local- to global-scale domains, to the real-time application of models as part of the Atmospheric Release Advisory Capability (ARAC), which is the designated national response center in the event of potential or actual releases of radionuclides to the environment. During FY 1989, about two-thirds of the support for our research came from the various parts of the U.S. Department of Energy (DOE); the rest came from the U.S. Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA), and other agencies and industrial concerns, and from within the Laboratory (see Table 1 and Appendix C, which lists each funded project for FY 1989).

We actively participate in workshops, meetings, and programs at the national and international level, report on our studies in articles in popular and professional publications, and invite others to visit and work with us. (See Appendix D for a list of special outside activities by our staff members, Appendix E for a list of our publications and meeting presentations, and Appendix F for a list of invited speakers for the Division.)

In our research, we use models to improve our understanding of the atmosphere-geosphere system. These models:

- Provide a basis for investigating and understanding causes, feedbacks, and responses and for testing hypotheses on how the atmosphere behaves.
- Are an essential tool in the design of experimental programs and provide the framework within which to interpret and understand observations.
- Can assist in determining the optimal locations for observations to be taken and in developing an observational strategy for investigating issues of importance.
- Can be used to estimate the accuracy required for instruments and their potential value for measuring variables of interest.
- Provide the basis for generalizing localized results and for projecting future conditions.

G-Division maintains a suite of atmospheric models capable of simulating the complex set of dynamic, physical, and chemical interactions that occur upon release or injection of energy-related species into the environment. These models have been and continue to be applied to problems of national and international importance. Table 2 summarizes the set of core modeling capabilities now available in the Division; these capabilities provide the basis for the research conducted by our various thematic groups. Appendix G provides a short description of the models being used in the Division, with points of contact listed as references for further information. A list of acronyms and abbreviations is included as Appendix H.

Table 2. Core Modeling Capabilities.

Transport, Diffusion, Deposition, and Hydrodynamic Models

- 3-D models of local-, regional-, and global-scale dispersion and deposition of radionuclides.
- 2-D and 3-D global fallout models of the consequences of occurrences such as nuclear war and power plant accidents.
- 2-D and 3-D cloud scavenging models.
- 2-D and 3-D heavy-gas dispersion models, including phase change and complex terrain.
- 2-D and 3-D general viscous, incompressible flow, and thermal convection models.
- 2-D and 3-D heavy-gas dispersion models.
- 2-D and 3-D nonhydrostatic planetary-boundary-layer models using finite-element methods.
- 1-D (quasi-3-D) model for heavy-gas dispersion in flat terrain.

Cloud Dynamics Models

- 3-D nonhydrostatic, compressible plume, storm, and mesoscale simulation system.
  - Dry version
  - Warm cloud version
  - Ice-bearing cloud version
  - Aerosol physics module for all three versions
- 3-D nonhydrostatic, compressible cloud model with boundary layer physics.
- 2-D nonhydrostatic, compressible cloud model with terrain.
- 3-D hydrostatic mesoscale model with cloud processes.

Atmospheric Chemistry, Microphysics, and Radiation Models

- 3-D regional photochemical-transport model.
- 3-D tropospheric chemistry and deposition model.
- 3-D aerosol, chemistry, and climate model.
- 2-D and 3-D global tracer models.
- 1-D and 2-D global chemical-radiative-transport models with coupled feedbacks.
- Detailed microphysics model of aerosol and warm rain processes.
- Detailed gas-to-particle formation model with aqueous chemical interactions.
- 1-D solar and infrared radiative transfer models.

Climate

- 3-D general circulation models of the global atmosphere.
- 3-D general circulation model of the troposphere.
- 3-D general circulation model of the global ocean.
- 3-D two-layer dynamic model of the global ocean.
- 1-D and 2-D simplified climate models of the atmosphere and oceans.

Division Organization: Thematic Roles, Capabilities and Accomplishments, and Key Issues

The Atmospheric and Geophysical Sciences Division (G-Division) is administratively part of the Physics Department at LLNL. G-Division is also involved in research and application studies for and with many other parts of the Laboratory and other governmental agencies. To meet these broad programmatic efforts, the Division is organized into seven thematic groups (see Fig. 1). The following sections summarize the roles, capabilities and accomplishments, and key issues for each of the groups, followed by a more detailed description of each thematic group's focus. Figure 2 is a piechart showing the relative funding for each group.

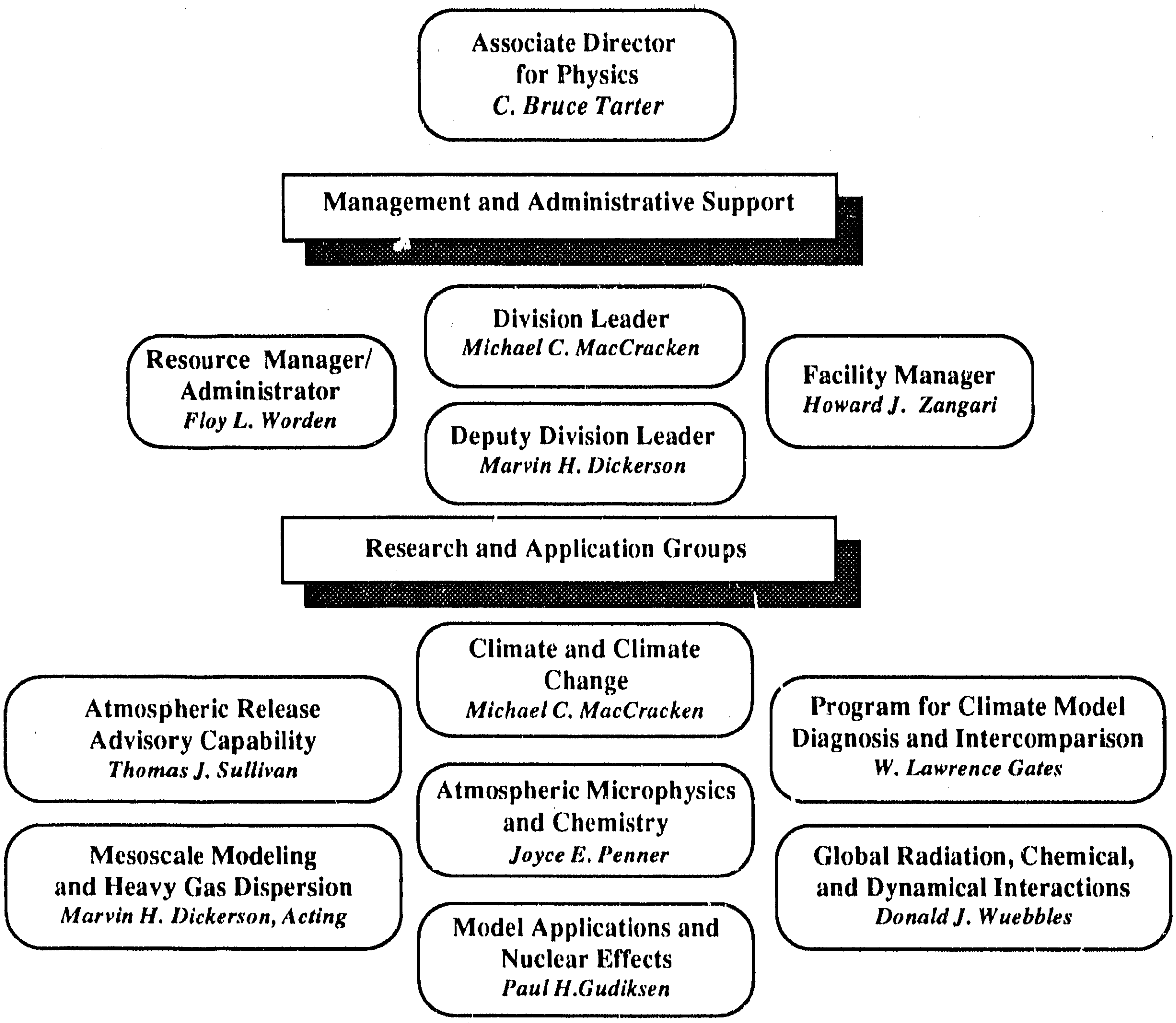

Figure 1. Organizational chart showing the seven thematic groups of G-Division.

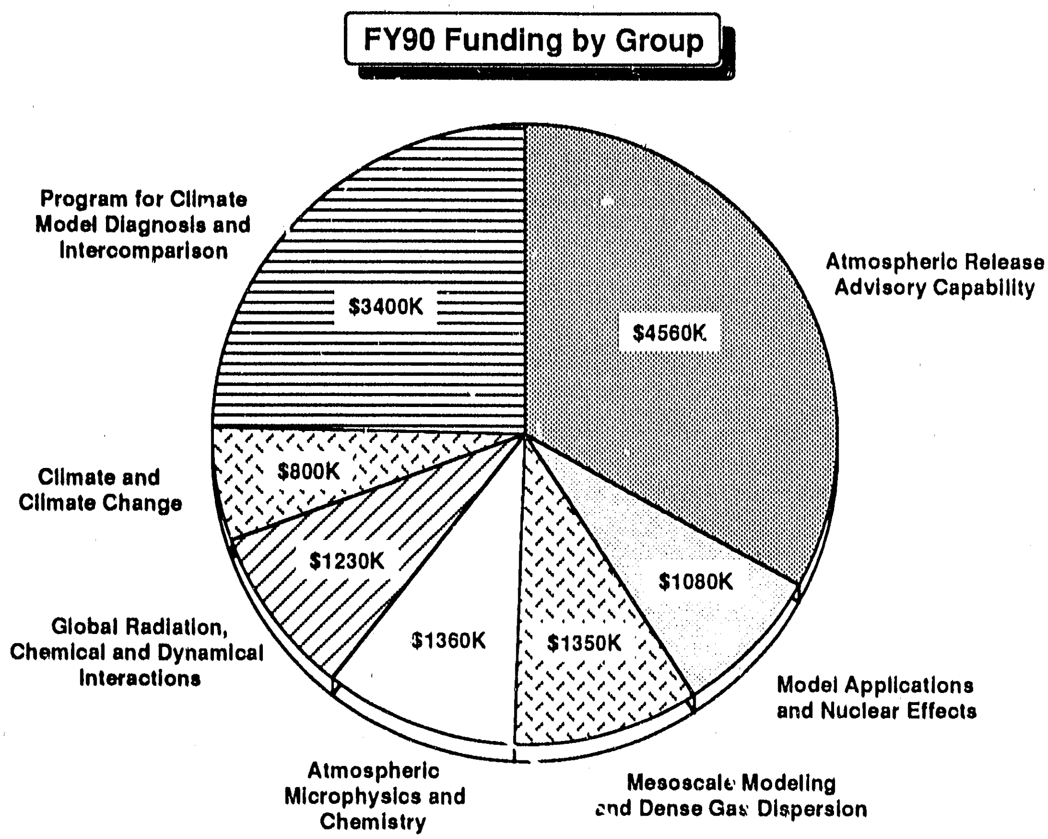

Figure 2. Piechart showing the relative funding for each group in G-Division.

Atmospheric Release Advisory Capability (ARAC) Group

Role

The ARAC group is responsible to the DOE, the DOD, and other national agencies under the auspices of the Federal Radiological Emergency Response Plan (FRERP) for developing and providing real-time assessments of the atmospheric transport, dispersion, and deposition of radionuclides in the event of potential or accidental releases of radionuclides into the atmosphere. ARAC serves as a key emergency preparedness training resource for more than 70 of the DOE and DOD facilities.

Capabilities and Accomplishments

- Currently serves more than 70 DOE and DOD sites.
- Timely responses to more than 300 exercises and all major accidents, including Three Mile Island, Titan II missile, Soviet satellite reentry, and Chernobyl.

Key Issues

- Expand services to include remaining DOE sites within two years and off or outside the continental U.S. (OCONUS) DOD sites.
- Growth to 24-hour immediate response (<30 minutes).
- Develop new-technology site workstations.
- Provide meteorological prediction instead of assumption of persistence.
- Extend capabilities to include the release of classes of nonradiological toxics.
- Provide international connections and technology transfer.

Focus

ARAC is responsible to the DOE, the DOD, and other national governmental agencies for providing real-time assessments of the transport, dispersion, and deposition of radionuclides in the event of potential or accidental releases of radionuclides into the atmosphere. In addition to the DOE and the DOD, ARAC provides the major assessment capability for the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and the Federal Aviation Administration (FAA) when radioactive material has been released into the atmosphere.

The major focus of this group is to provide an emergency planning, response, and assessment service to the various government agencies. A considerable amount of ARAC's time is devoted each year to supporting emergency response exercises conducted by the individual sites and various federal agencies. Currently, the sites consist of more than 70 DOE and DOD facilities and military bases that are connected directly to the ARAC center via modems and computers. As a result, a large part of ARAC's effort involves dealing with the various individual client needs and requirements. At this time, the center is staffed 40 hours per week for an immediate response (<30 minutes), and the off-hours are covered by a callout of available staff (~90-minute response). ARAC currently has about 25 staff members. Their experience encompasses meteorology, health physics, computer science, engineering, and computer utilization and support. Within two years, we expect that growth in the ARAC service and support will lead to an increase in staff and will provide the capability for an immediate response on a 24 hours-per-day basis using "at home" workstations and a quick-recall staff program.

The ARAC center is connected to Air Force Global Weather Central (AFGWC) to provide on-demand access to near real-time meteorological data from virtually every place in the world that reports measurements of wind speed and direction, temperature, pressure, etc. For particular locations in the U.S., these data are automatically transmitted every hour to the ARAC computers, where they are stored and are readily accessible if needed. As previously stated, more than 70 DOE and DOD facilities are connected directly to the ARAC center with computers, which transmit accident or event parameters and site meteorological data to the center and receive assessment products from the center.

For locations not initially specified as possible accident sites (e.g., Chernobyl), site-specific databases can be rapidly developed by the skilled ARAC staff and can be incorporated in the assessments. For example, the terrain data for the continental U.S. is on-line and accessible in about two minutes, with a horizontal resolution of 0.5 km. These data are used directly in the assessment models; colored and shaded graphical images visualize topographical details such as mountains and valleys. Assessment models on-line in the center are capable of addressing a wide range of accidents, varying from nuclear power plants and atmospheric tests (e.g., Chinese) to nuclear weapons accidents and accidents at DOE facilities. The main computers are the Digital Equipment Corporation's VAX-class machines configured to provide real-time data assimilation, model calculations, and analysis. Approximately 1.2 million lines of computer code have been written during the past six years to form the basis for this real-time system.

In addition to providing the base service to the DOE and the DOD, this group also focuses on improving and extending its capabilities. For example, our response to the Chernobyl accident led us to expand the scale of modeling from regional to global, and to assemble hemispheric wind field data sets from AFGWC every 12 hours. ARAC is now prepared to address in near real-time any accident in the Northern Hemisphere north of 20° latitude. As time and resources permit, this capability will be extended to the Southern Hemisphere and tropical regions to complete the development of a global response capability.

On the international scene, ARAC has participated directly with other countries and the Commission of European Communities (CEC) to help improve their emergency response systems and has worked with the nuclear safety directorate within the International Atomic Energy Agency (IAEA). Staff members have helped review emergency response systems for developing countries and have participated in developing and writing Safety Series documents, which are guides (published in six languages) that recommend procedures to follow in order to meet certain safety standards. These particular Safety Series documents are used by countries throughout the world as guides for planning and implementing emergency response systems for nuclear facilities.

We have begun to investigate toxic-chemical emergency response capabilities and to determine how they might be integrated into the ARAC structure. Consolidation into G-Division of the Laboratory's research project on spills of heavier-than-air gases is permitting us to accelerate our efforts to extend ARAC to treat accidental releases of toxics and heavier-than-air gases, both of which pose serious potential public health threats as the result of accidents involving the storage of such materials at federal facilities or transport on trains, on highways, and in harbor areas. In addition, G-Division's modeling and microphysics expertise are being used to further expand heavy-gas modeling capabilities, particularly as they relate to the complex physical characteristics of gases such as UF_6. These combined resources will provide a powerful tool for expanding the ARAC service to include toxic-chemical and heavy-gas emergency planning, response, and assessment activities.

Model Applications and Nuclear Effects Group

Role

The Model Applications and Nuclear Effects Group is responsible for the development and application of computer models that simulate the release, atmospheric dispersion, and deposition of radionuclides. The functional capabilities of these models, which range from the generation of source terms to the estimation of environmental impacts, are presently being extended to toxic chemicals.

Capabilities and Accomplishments

- Maintains the technical expertise and the advanced numerical modeling framework required to assess the environmental impact of atmospheric releases of radioactivity.
- Developed a suite of models for the treatment of local- to global-scale dispersion and fallout of radioactivity.
- Performed detailed evaluation of the source term, atmospheric dispersion, and dose estimation resulting from the Chernobyl reactor accident.
- Performs risk assessment studies of weapons-related operations and dose assessments related to various nuclear war scenarios.
- Performs meteorological field experiments to acquire the data needed for model development and evaluation.

- Evaluates the performance of dispersion models against data from both local- and long-range field studies.
- Performs modeling studies on the scavenging of aerosols by cloud droplets due to electrical attachment processes.

Key Issues

- Integration of modeling capabilities across spatial and temporal scales.
- Extension of modeling capabilities to include the dispersion of toxic chemicals.
- Collaboration with other laboratories in meteorological field experiments.

Focus

The focus of the Model Applications and Nuclear Effects Group is on the development of models that are capable of accurately assessing the environmental impacts resulting from the release, atmospheric dispersion, and deposition of radionuclides. This group, which is composed of physical and computer scientists, is supported by consultants from outside the Division.

The development of dispersion models involves participation in multilaboratory research programs designed to increase our knowledge of the physical processes responsible for pollutant dispersion. This includes performing joint field experiments in complex terrain areas, data analysis, and model development. These efforts are currently focused on supporting DOE's emergency preparedness plans at specific DOE facilities. In the model applications area, we applied our models to (1) the simulation of the global-scale dispersion of the radioactivity released from the Chernobyl reactor accident, and the estimation of the radionuclide specific source terms, (2) the dispersion over Europe of the radioactive material vented from underground nuclear weapon tests within the Soviet Union, and (3) risk assessments associated with operations at nuclear facilities.

The models are currently being improved by the inclusion of improved wind fields, a more realistic diffusion scheme, and a localized rainout module. Upon inclusion of these improvements, the models will be evaluated against experimental data acquired from tracer experiments, as well as from the Chernobyl reactor accident. Techniques for improving the source term and dose estimation processes through integration of measurements with the model predictions are currently being explored. Another task involves the direct incorporation of dose models into a chain of calculations that would enable us to estimate the dose-to-humans through a variety of pathways. Based on our experience with nuclear materials and the experimental data acquired from DOE's Liquefied Gaseous Fuels (LGF) program, we plan to extend our modeling capability to the dispersion of toxic chemicals.

Mesoscale Modeling and Heavy Gas Dispersion Group

Role

The Mesoscale Modeling and Heavy Gas Dispersion Group is responsible for developing, experimentally evaluating, and applying advanced fluid dynamical models for use in mesoscale and heavy gas dispersion studies and for investigation of specialized problems.

Capabilities and Accomplishments

- Hierarchy of one-, two-, and three-dimensional, finite-element, hydrostatic and nonhydrostatic models.
- Model application to: stably stratified flows, gravitational spreading of heavier-than-air gases, flows around buildings, and atmospheric flow in complex terrain (ASCOT).

Key Issues

- Development of a mesoscale forecast model for ARAC.
- Support for continued numerical method advancement.
- Incorporation of more physics and chemistry into the heavy gas model.
- Development of a new representation for turbulence.
- Interface heavy gas research results into ARAC emergency response capability.
- Application of research results to federal, state, and local problems.

Focus

The goals and activities of this group are threefold: development of new and better fluid mechanics (and transport and diffusion) models; application of existing models to current areas of interest and concern; and specialized support to other groups in the Division, to LLNL, to DOE, and to other federal agencies.

The mesoscale modeling efforts are divided into two major areas: nonhydrostatic and hydrostatic; and, because hydrostatic models are less expensive to run on the computer, part of the charter of the group is to better understand and describe those conditions under which the hydrostatic approach is an acceptably accurate approximation of the actual nonhydrostatic conditions. Our current mesoscale model is a nonhydrostatic finite-element model that is useful for simulating small-scale and/or locally driven phenomena such as drainage flow in complex terrain.

Several current fluid dynamics models that solve either the incompressible Navier-Stokes or Boussinesq equations, or the anelastic equations, also exist. These are also finite-element models and are (or have been) used to accurately compute isothermal flows (e.g., vortex shedding behind a cylinder), thermal convection flows (both in air and in other fluids, some a bit more exotic such as liquid uranium), and stably stratified flows. These models are currently being used to investigate flows around buildings, with pollutants embedded in the flow fields.

Hydrostatic mesoscale models are currently under construction, based on both finite-element and finite-difference techniques. One of these models will be tailored to meet ARAC's needs and will be delivered to them as a forecast model to replace their current persistence forecast assumption. Other versions of these models should find uses both in larger-scale studies of flows in complex terrain and in studies of toxic releases that are of neutral or near-neutral buoyancy.

Over the last few years, our efforts in the model development area have produced two widely recognized heavy-gas dispersion models, FEM3 and SLAB. The addition of a detailed description of the thermodynamics associated with two-phase (liquid aerosol and vapor) release to the atmosphere is planned for the SLAB (one-dimensional, quasi-three-dimensional) heavy-gas dispersion model. Improvements planned for the FEM3 (three-dimensional finite-element) model will consider improved two-phase thermodynamics and a more advanced turbulence parameterization. All model improvements are tested thoroughly using field data taken from our various field tests.

Planned support activities of this group for other groups in the Division are directed toward, but not limited to: ARAC Group, Model Application and Nuclear Effects Group, and Atmospheric Microphysics and Chemistry Group. The Mesoscale Modeling and Heavy Gas Dispersion Group has also been called on in the past to provide computational fluid dynamics support to other (nonatmospheric/geophysical) programs at LLNL, and it expects to continue to do so in the future.

Atmospheric Microphysics and Chemistry Group

Role

The Atmospheric Microphysics and Chemistry Group is responsible for advancing the understanding of the physical, radiative, and chemical interactions of species injected into the lower atmosphere—generally short-lived, photochemically active species that impact the boundary layer and troposphere on regional to global scales. Recently two areas within this broader scope have been emphasized. One is the improvement of global climate models through the development of coupled climate models and chemistry-transport models to study tropospheric trace gas and aerosol distributions and their effects on climate. The second is through the development of dynamical cloud models with the capability to treat trace species and aerosol interactions. These models are used to study the dynamics and microphysics of convective and stratiform clouds and aerosol-cloud interactions with the aim of improving the parameterization of clouds and cloud processes in general circulation models (GCMs).

Capabilities and Accomplishments

- Detailed gas-to-particle formation model with aqueous- and gas-phase chemistry.
- Detailed size-resolved aerosol/water drop microphysics model.
- Three-dimensional regional photochemical air-quality model.
- Global tropospheric model of atmospheric chemical transformation and budgets.
- Coupled global climate, chemistry, and aerosol model.
- Three-dimensional, nonhydrostatic, dynamic and microphysical cloud/mesoscale model including ice physics.
- Three-dimensional, nonhydrostatic aerosol-cloud interaction model.
- Three-dimensional, hydrostatic dynamic and microphysical mesoscale planetary-boundary-layer model.

Key Issues

- Development of three-dimensional global tropospheric chemistry, aerosol, and climate model.
- Study of the interaction of aerosols and cloud microphysics.
- Study of the effects of regional atmospheric chemical transformations on global tropospheric chemistry.
- Study of the dynamics and microphysics of postnuclear-exchange smoke plumes.
- Parameterization of the life cycle and radiative effects of stratus, cirrus, and convective clouds in general circulation models.

Focus

A major research focus of the Atmospheric Microphysics and Chemistry Group is studying the fate of aerosols (and gases that form aerosols) that are injected into the atmosphere. A detailed microphysical model has been developed that simulates the evolution of the size distribution of particles injected into the atmosphere (for example, smoke from biomass fires) as they rise into a cloud. The group is also using a variety of models to study the role of anthropogenic and natural emissions of sulfur in the atmosphere, the transformation of gas-phase sulfur to aerosol, and the impact of aerosols on climate.

The group is also concerned with changes in the gaseous composition of the atmosphere. A global, three-dimensional photochemical transport model has been developed to treat nitrogen oxide (NO_x) transformation to nitric acid and to evaluate the long-term transport and impact of anthropogenic NO_x emissions. Expansion to treat more complex photochemical cycles is underway so that prediction of global O_3 fields and OH will be possible very soon. In the future, we plan to investigate the role of regional atmospheric chemical transformations as sources of O_3 and OH in the global atmosphere.

A unique, state-of-the-art, three-dimensional, dynamic and microphysical cloud/mesoscale model has also been developed by the group. This model has been used to study the atmospheric circulations and microphysical processes above large, postnuclear-exchange fires in order to better define the smoke source term for our Environmental Effects of Nuclear War program. The model simulates the complex interactions of smoke particles with the liquid and ice hydrometeors formed in fire-induced convective clouds. The model is applicable to a wide range of cloud and mesoscale atmospheric problems and will be used to assist in the development of improved cumulus, stratus, and cirrus cloud representations and their parameterization in global climate models.

Global Radiative, Chemical, and Dynamical Interactions Group

Role

The Global Radiative, Chemical, and Dynamical Interactions Group works to advance our understanding of the radiative, chemical, and dynamical processes that determine the state of the global atmosphere, particularly with respect to the troposphere and stratosphere. Emphasis is on modeling the basic processes and the interactions of these processes, comparing our modeling results with observations, and determining the potential impacts of human influences.

Capabilities and Accomplishments

- Provide reference simulations for international assessments of the effects of chlorofluorocarbons, supersonic transports, nuclear weapons, and other human-induced perturbations on atmospheric ozone.
- Perform analyses to be used in assessing how the changing composition of greenhouse gases will affect climate.
- Develop integrated measures of the relative effects of various trace gas emissions on ozone and climate.
- Provide science team members for Upper Atmosphere Research Satellite (UARS) project.
- Develop one- and two-dimensional global chemical-radiative-transport models of the troposphere and stratosphere.
- Develop one-dimensional radiative transfer models.

Key Issues

- Coupling of two-dimensional chemical-radiative-transport models with climate models.
- Increased funding for chemistry-climate interactions studies.
- Improving the capabilities of radiative transfer models for atmospheric chemistry and climate studies.
- Development of three-dimensional chemical-radiative-transport modeling capabilities.

Focus

Research in the Global Radiative, Chemical, and Dynamical Interactions Group is aimed at studying the radiative, chemical, and dynamical processes that determine the state of the global atmosphere, particularly with respect to the troposphere and stratosphere on global scales. Much consideration is given to studying the interactions between the various processes. The one- and two-dimensional models developed to date to study these processes and their interactions have been extensively used in national and international assessments of the effects that trace gases emitted into the atmosphere may have on the global distributions of ozone and temperature. Scientists in this group, as well as their research accomplishments, have also played major roles in the consideration of potential regulatory actions of trace gas emissions at both national (e.g., FAA, EPA, and DOE) and international (e.g., United Nations Environmental Programme, Organization for Economic Cooperation and Development (OECD), and World Meteorological Organization) levels.

For these studies, we have developed and are applying one- and two-dimensional radiative-chemical-transport models to study tropospheric and stratospheric processes. Our two-dimensional model is a state-of-the-art tool for the study of atmospheric physical and chemical interactions; it includes the capability of analyzing the effects of longer-lived trace constituents emitted at the Earth's surface or the effects of gases injected directly into the atmosphere. To aid in these studies, we are developing radiative transfer models to determine absorption and scattering properties of the atmosphere and their resultant effect on atmospheric temperatures. Analyses using the above models are being conducted to study the impacts that trace gases, including chlorofluorocarbons, CH_4, CO_2, and NO_x, will have on the global atmosphere. Past, present, and possible future states of the atmosphere are being examined with the models in an attempt to better determine existing limitations in our understanding of atmospheric processes and interactions. In support of the DOE's Carbon Dioxide Research Program, we are conducting studies, using the above models in collaboration with models of climatic processes, to examine the effects of trace gases on climate.

We are also beginning the development of a next generation, three-dimensional, chemical-radiative-transport model, with the intention that this model can be fully coupled with global climate models.

To assist in observational studies, we are serving as science team members (as theoretical investigators) in the preparations for launching NASA's UARS. After this satellite is launched (expected in mid-1991), we will use the incoming satellite data in conjunction with our models to improve our theoretical understanding of stratospheric and lower mesospheric processes.

Climate and Climate Change Group

Role

The Climate and Climate Change Group is responsible for advancing our understanding of the mechanisms and nature of climate change (primarily those changes resulting from factors affecting atmospheric composition) by using climate models and comparing the results from these models with observational data.

Capabilities and Accomplishments

- One-, two-, and three-dimensional models of the atmosphere and three-dimensional models of the ocean.
- Interactive simulations of climate and composition changes, including treatment of perturbations resulting from sulfur emissions, postnuclear smoke, and volcanic eruptions.

- Participation in the University of California Institute for Collaborative Research (InCoR) on Atmospheric and Oceanic Modeling for Climate Change with Los Alamos National Laboratory and the Scripps Institution of Oceanography.
- Lead responsibility for preparing the DOE multilaboratory report on *Energy and Climate Change* and the U.S./U.S.S.R. report on *Prospects for Future Climate.*

Key Issues

- Development of coupled two- and three-dimensional ocean-atmosphere models for use in transient climate studies.
- Organization of and participation in DOE's Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) Initiative to develop an advanced generation climate model.
- Enhancement of collaborative research programs on Earth System Modeling within LLNL, with other campuses of the University of California, and with the wider university community.

Focus

The Climate and Climate Change Group studies the mechanisms that control climate change. Research ranges from study of the role of interactions between individual processes as they affect the climate (e.g., cloud interactions with solar and infrared radiation) to integrated studies of the effects of gaseous and aerosol changes on atmospheric and oceanic conditions.

One current objective is to reduce the uncertainty in projections of future climate change that would result from changes in atmospheric composition. Because the reliability of current atmospheric models is limited by insufficient understanding of cloud feedback effects, we are analyzing the role of clouds and their effects on radiation using available climate models. In particular, we are determining whether better treatments of cloud radiative properties (as determined by the cloud liquid water content and the abundance of cloud condensation nuclei) significantly improve the climate simulations. This work is being coordinated with the new DOE Atmospheric and Radiation Measurement (ARM) Initiative, which will provide data for model validation.

A second goal of our research is to sharpen our understanding of the rate of climate change, that is, to determine how quickly the climate responds to changing atmospheric composition. This involves the use of a simplified zonally-averaged atmosphere-ocean model and full three-dimensional ocean models; the latter will eventually be coupled to our existing suite of three-dimensional atmospheric models.

We also provide scientific advice and support to the headquarters staff of the DOE's CO_2 research program. This effort, which began about ten years ago, includes editing and co-authoring state-of-the-art reports on projecting and detecting CO_2-induced climate change, preparing a DOE multilaboratory report on *Energy and Climate Change*, and co-editing and co-authoring the U.S./U.S.S.R. report on *Prospects for Future Climate.*

Since the initial suggestion in 1982 that smoke from postnuclear fires could affect the climate, we have been using our models to estimate the potential climatic effects of massive smoke injections from fires started by a nuclear war. We were the first group to treat moving smoke, to simulate the sharp reduction in precipitation over land, and to extend interactive ocean-atmosphere calculations to study potential effects the year following the war.

The Physics Department's Institutional Research and Development (IR&D) program has provided support for modifying and adapting atmospheric and oceanic general circulation models for our use in studies of CO_2-induced climate change, "nuclear winter," and other atmospheric perturbations. These efforts are intended to help build the underlying framework for the continued growth of our global change studies.

Program for Climate Model Diagnosis and Intercomparison (PCMDI)

Role

The PCMDI is charged with the design and execution of a systematic program of diagnosis and intercomparison of global climate models and with the establishment and promotion of advanced standards in climate model experimentation, validation, and visualization.

Capabilities and Accomplishments

- Global atmospheric and oceanic models for climate simulation.
- Diagnostic software for radiation/energy balances.
- Storage and retrieval system for very large databases.
- Visualization software for database diagnosis.
- Model-consistent observational climate database.
- Leadership of international climate model intercomparison activities.

Key Issues

- Climate simulation with the European Centre for Medium Range Weather Forecasts (ECMWF) model at T106 (about 100 km) resolution.
- Development of strategies for model diagnosis, including cloud/radiation feedback.
- Preparation for extended simulation with oceanic GCMs.

Focus

The Program for Climate Model Diagnosis and Intercomparison (PCMDI) was established in 1988 in response to the need for increased understanding of the differences between the simulations of climate and climate change produced by current GCMs.

These simulations involve the extended iterative solution of the coupled nonlinear dynamical equations governing the atmosphere, the realistic parameterization of important subgrid-scale processes such as cloudiness/radiation, convection and surface hydrological effects, and the prescription of realistic boundary conditions. Over the past decade or so, approximately a dozen models have met these requirements and have demonstrated an ability to simulate the observed large-scale structure of the mean seasonal climate with reasonable accuracy. When applied to the problem of simulating the likely climatic effects of increased atmospheric CO_2, however, such models show significant disagreements on local and regional scales and display a marked sensitivity to the treatment of clouds. Closer examination reveals that the simulated climate, especially on smaller scales, is sensitive to virtually all of the physical and numerical processes in the model. It is also increasingly recognized that there are serious systematic errors in the reference or control climates of all models, and that extant climate simulations have not been made (or verified) under comparable conditions.

In an attempt to bring some order to the practice of climate modeling and to lay a basis for systematic model improvement, the PCMDI was established by the Atmospheric and Climate Research Division of the DOE Office of Health and Environmental Research (OHER). As the initial steps in a long-range strategy of numerical experimentation to establish the sensitivity of simulated climate to model formulation and parameterization, the PCMDI is focusing on the effects of horizontal model resolution and on the role of clouds. In the former area, the PCMDI, in cooperation with the ECMWF, whose model has been selected as the first of an eventual suite of models, is undertaking a set of parallel simulations with four different resolutions that span (and increase by about a factor of three) the resolution of current climate models. These simulations are the first to be made under standard conditions as recommended by the World Climate Research Program, and they will be systematically examined with comprehensive diagnostic and visualization software now being developed. A model-oriented climate database and a climate model information system are also under construction.

In cooperation with the international modeling community, the PCMDI is also undertaking detailed analyses of cloud/radiative feedback in climate models under a DOE-sponsored model intercomparison project. Preliminary results show a three-fold variation in the sensitivity of current models to the effects of clouds. New simulations are underway with a high resolution version of the ECMWF model and the results are being compared with climatic data on the Earth's radiation budget provided by satellites.

The PCMDI's long-range program is designed to: carry out systematic numerical experimentation with representative climate models in order to establish the modeled climate's sensitivity to formulation, parameterization, and forcing; promote standards in climate model design, simulation, validation, diagnosis, documentation, and intercomparison; develop innovative software for visualization and diagnosis; develop a comprehensive model-oriented climate database; and promote increased coordination and cooperation in the climate modeling community.

Acknowledgments

We appreciate the efforts of Doris Gresho and Raylene Cooper in preparing and assembling this report, Elaine Price for her editing, and Duane Hoepker for his cover design. The work described in this report is supported by the U.S. Department of Energy and other agencies and is performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract W-7405-ENG-48. For further information, individuals mentioned in this report may be reached through the Division Office, telephone 415-422-1800 (FTS 532-1800) or by writing to the Division Leader, Atmospheric and Geophysical Sciences Division, Lawrence Livermore National Laboratory, P.O. Box 808 (L-262), Livermore, CA 94550.

Appendix A. Division Scientists and Supporting Staff

G-Division Scientific Staff

Name	Research Interests	Highest Degree	School
Cynthia S. Atherton	*atmospheric chemistry*	M.S.	MIT
Michael M. Bradley	*cloud dynamics, microphysics, and mesoscale meteorology*	Ph.D.	U. Illinois, Urbana
Stevens T. Chan	*computational fluid dynamics, heavy-gas dispersion*	Ph.D.	U. of Calif., Davis
Peter S. Connell	*photochemical kinetics*	Ph.D.	U. of Calif., Berkeley
Curtis C. Covey	*fluid-dynamical simulation*	Ph.D.	U. of Calif., Los Angeles
Marvin H. Dickerson	*real-time dose modeling, model evaluation*	Ph.D.	Florida State U.
Leslie L. Edwards	*numerical modeling; atmospheric microphysics, hydrodynamics*	M.A.	U. Oregon
James S. Ellis	*remote sensing of climatic change*	Ph.D.	Colorado State U.
Donald L. Ermak	*turbulence, atmospheric heavy-gas dispersion*	Ph.D.	U. of Calif., Davis
Kevin T. Foster	*boundary layer meteorology*	M.S.	U. of Calif., Davis
W. Lawrence Gates	*climate dynamics*	Ph.D.	MIT
Steven J. Ghan*	*climate dynamics*	Ph.D.	MIT
Keith E. Grant	*radiation transport, uncertainty analysis, transport-kinetics models*	Ph.D.	U. of Calif., Davis/Livermore
George D. Greenly, Jr.	*planetary boundary layer meteorology*	M.S.	U. Oklahoma
Philip M. Gresho	*computational fluid mechanics, numerical methods, finite elements*	Ph.D.	U. Illinois, Urbana
Stanley L. Grotch	*data analysis*	Ph.D.	MIT
Paul H. Gudiksen	*radiological impact studies, meteorological measurements*	Ph.D.	U. Washington
Ted F. Harvey	*aerosol science, environmental radiation, source terms*	Ph.D.	U. of Calif., Davis
Joseph B. Knox†	*atmospheric sciences, climate change*	Ph.D.	U. of Calif., Los Angles
Ronald Koopman**	*heavy gas dispersion, accidental release of toxics*	Ph.D.	U. of Calif., Davis
Rolf Lange	*turbulence and diffusion*	Ph.D.	U. of Calif., Davis
Robert L. Lee	*planetary boundary layer modeling*	Ph.D.	U. of Calif., San Diego
John M. Leone, Jr.	*atmospheric numerical modeling*	Ph.D.	Iowa State U.

* Current affiliation: Battelle Pacific Northwest Laboratory

† Primary affiliation: U. of Calif., Davis

** Current affiliation: Energy Program, LLNL

G-Division Scientific Staff (Continued)

Name	Research Interests	Highest Degree	School
Michael C. MacCracken	*global climate studies, climate modeling*	Ph.D.	U. of Calif., Davis/Livermore
John W. McClure	*physics*	B.S.	U. Southern California
Mary K. Meyer	*climate dynamics*	M.S.	U. of Wisconsin, Madison
Connee S. Mitchell	*atmospheric dispersion modeling, emergency response*	M.S.	Oregon State U.
Charles R. Molenkamp	*cloud microphysics, precipitation scavenging, cloud and mesoscale modeling*	Ph.D.	U. Arizona
Joyce E. Penner	*microphysics, atmospheric chemistry, and climate change*	Ph.D.	Harvard U.
Linda G. Peters	*physics*	M.S.	Colorado School of Mines
Thomas J. Phillips	*climate dynamics, numerical modeling, statistical diagnostic analysis*	Ph.D.	U. of Wisconsin, Madison
Gerald L. Potter	*climate change and model sensitivity studies*	Ph.D.	U. of Calif., Los Angeles
Daniel J. Rodriguez	*model evaluation and boundary layer studies*	M.S.	San Jose State U.
Leonard C. Rosen	*atmospheric optics, wave propagation, radiation transport*	Ph.D.	Columbia U.
Thomas J. Sullivan	*mesoscale meteorology, air pollution, emergency assessment*	Ph.D.	U. of Calif., Davis
Karl E. Taylor	*climate dynamics, atmospheric dynamics*	Ph.D.	Yale U.
John J. Walton	*modeling and code development, global transport and dispersion*	Ph.D.	U. Kansas
Donald J. Wuebbles	*atmospheric chemistry, chemical-climate interactions, numerical modeling*	Ph.D.	U. of Calif., Davis

G-Division Administrative and Technical Supporting Staff

Name	Position
Julia J. Bagorio	Assistant Resource Manager
Marilyn B. Borton	Administrative Specialist
Raylene Cooper	Information System Specialist
Pamela M. Drumtra	Administrative Specialist
K. Patrick Ellis	Field Support
Doris G. Gresho	Administrative Specialist
Pearline Hassan	Librarian
Linda S. Kennedy	Administrative Specialist
Broox L. McLemore	Administrative Specialist
Mabel K. Moore	Administrative Specialist
Lonnette L. Robinson	Information System Assistant
Floy L. Worden	Resource Manager/Administrator
Howard J. Zangari	Facilities Coordinator

Affiliated Staff

Name	Affiliation	Discipline	Highest Degree	School
Rosemary O. Abriam	1	*computer science, biology*	B.S.	Calif. State U., Hayward
Ronald L. Baskett	4	*atmospheric sciences*	M.S.	U. of Calif., Davis
Richard D. Belles	1	*applied science*	M.S.	U. of Calif., Davis
Diane F. Bonner	1	*mathematics*	B.S.	State U. of N.Y., Albany
Sharon C. Braley	1	*general education*	A.A.	Chabot College
Richard T. Cederwall	3	*meteorology*	M.S.	San Jose State U.
Stephen P. Cooper	1	*computer science*	B.S.	Purdue U.
Thomas G. Corsetti	1	*atmospheric science*	M.S.	State U. of N.Y., Albany
J. Daryl Crew	1	*mathematics*	M.S.	Calif. State U., Hayward
Dee Ann R. Davi	4	*mathematics*	B.A.	Westmont College
Robert S. Drach	1	*mathematics*	M.S.	Ohio University
Harold E. Eddleman	1	*electronic engineering*	B.S.	U.S. Naval Postgraduate School, San Diego
Robert P. Freis	1	*engineering science*	M.S.	U. of Calif., Berkeley
Donald A. Garka	2	*electronics engineering*	B.S.	Devry Inst. Tech.
Yolanda G. Glaeser	4	*general education*	A.A.	Ohlone College
Glenn L. Hage	1	*mathematics*	B.A.	San Jose State U.
Anthony T. Hoang	4	*computer science*	—	San Jose State U.
John K. Hobson	1	*mathematics*	M.S.	U. of Calif., Berkeley
Leonard A. Lawson	1	*mathematics*	A.B.	Calif. State U., Chico
Ambrosio R. Licuanan	1	*computer science*	A.A.	Ohlone College
Mary Ann Mansigh	1	*mathematics, chemistry*	B.S.	U. Minnesota, Duluth
Rose C. McCallen	2	*mechanical engineering*	M.S.	U. of Calif., Davis
Robert L. Mobley	1	*mathematics/physics*	B.S.	N.E. Missouri State U.
R. Miki Moore	1	*computer science*	M.A.	U. of Calif., Berkeley

Affiliated Staff (Continued)

Name	Affiliation	Discipline	Highest Degree	School
Louise K. Morris	1	*mathematics*	B.S.	U. of Calif., Davis
John S. Nasstrom	4	*atmospheric sciences*	M.S.	U. of Calif., Davis
Charles J. O'Connor	1	*computer science*	M.S.	Calif. State U., Hayward
Walter W. Schalk, III	4	*meteorology*	M.S.	Florida State U.
Debra R. Sparkman	1	*computer science*	B.S.	U. of the Pacific
John L. Stout	5	*geological engineer*	M.S.	Colorado School of Mines
Denise A. Sumikawa	1	*computer science*	M.S.	U. of Calif., Davis
Raymond L. Tarp	1	*mathematics*	B.A.	San Jose State U.
Sandra S. Taylor	1	*computer science, statistics*	B.S.	Iowa State U.
David P. Turner	1	*math/computer science*	B.S.	Western Washington U.
Hoyt Walker	1	*computer science,*	M.S.	U. of Calif., Davis
		geography	M.A.	San Jose State U.
Jon G. Welch	2	*electronic technology*	—	Delta College/Chabot
Conrad A. Wilgus	1	*applied mathematics*	M.S.	Calif. State U., Sacramento
Dean N. Williams	1	*computer science*	M.S.	Calif. State U., Chico
Carolyn D. Wimple	1	*computer science*	B.S.	Calif. State U., Sacramento

1. Computations Department, Applications Development Division (LLNL)
2. Engineering Department (LLNL)
3. Environmental Sciences Division (LLNL)
4. EG&G
5. KMI

Participating Guests

Name	Research Interests	Degree	School
Hugh W. Ellsaesser (retired)	*atmospheric dynamics, climate change*	Ph.D.	U. Chicago
Howard C. Rodean (retired)	*turbulence, thermodynamics*	M.S.	Purdue U., Southern Methodist U.
Charles R. Veith (retired)	*emergency response*	—	—

Post-Doctoral Appointees

Name	Research Interests	School
Hung-Neng S. Chin	*atmospheric sciences*	U. Of Illinois, Urbana
Chien-Hua C. Chuang	*cloud physics, computational fluid dynamics*	U. Of Illinois, Urbana
Jane E. Dignon	*atmospheric chemistry, trace gas emissions, global change*	State U. of N.Y., Stony Brook
Douglas E. Kinnison	*trace-gas chemistry interactions*	U. of Calif., Berkeley
Kenneth R. Sperber	*air sea interactions, interannual variability*	State U. of N.Y., Stony Brook

Consultants

Name	Discipline	Organization
James F. Barbieri	*database management*	Naval Weapons Center
Alfred K. Blackadar	*meteorology*	Self-employed
Robert D. Cess	*mechanical engineering, atmospheric modeling*	State U. of N.Y., Stony Brook
Julius S. Chang	*atmospheric modeling*	State U. of N.Y., Albany
Robert M. Chervin	*computer modeling*	NCAR
Terry L. Clark	*mesoscale modeling*	NCAR
Robert G. Ellingson	*meteorology*	University of Maryland
Rudolph J. Engelmann	*atmospheric sciences*	Self- employed
Sultan Hameed	*atmospheric physics*	State U. of N.Y., Stony Brook
James R. Ipser	*theoretical astrophysics*	U. of Florida
Joseph B. Klemp	*fluid mechanics*	NCAR
Sonia M. Kreidenweis-Dandy	*aerosol nucleation*	San Jose State U.
Steven K. Krueger	*atmospheric sciences*	U. of Utah
Glen Rawson	*geology*	Self-employed
Robert L. Sani	*chemical engineering*	U. of Colorado
Charles S. Shapiro[1]	*dose assessment and effects of ionizing radiation*	Calif. State U., San Francisco
Julia M. Slingo	*meteorology*	NCAR
Gregory Taylor	*cloud physics and atmospheric chemistry*	Calif. State U., Chico
Robert B. Wilhelmson	*cloud dynamics*	U. of Illinois, Urbana
Morton G. Wurtele	*atmospheric dynamics*	U. of Calif., Los Angeles

[1] Also summer employee

Interest Areas of Scientific, Affiliated, and Technical Staff

Rosemary O. Abriam is interested in user interface issues and in artificial intelligence, specifically expert systems.

Cynthia S. Atherton is interested in computer modeling of the chemistry and physics of the atmosphere, with emphasis on the troposphere. Her work encompasses regional to global scales, and includes the atmospheric chemistry of the natural and polluted troposphere.

Ronald L. Baskett is interested in dispersion models on local and regional scales as applied to emergency response and air quality problems. He also works on integrating meteorological measurement systems into ARAC and evaluating the MATHEW/ADPIC models against tracer experiments.

Richard D. Bellos has a broad range of interests including scientific visualization, data communications, and model development and optimization. The images on the front and back covers of the accompanying issue of *Energy and Technology Review** were produced by his PERSPEC program, which was described in the Laboratory's January/February issue of the same publication.

Diane F. Bonner is interested in user interface design and VAX software engineering tools.

Michael M. Bradley has a broad range of interests, including numerical cloud and storm modeling, cloud microphysics, aerosol-hydrometeor interactions, and mesoscale modeling, especially in interactions of mesoscale and cloud-scale dynamics and flow over complex terrain. He is also interested in the parameterization of cloud processes in general circulation models.

Sharon C. Braley is interested in the areas of user interface, 4GL, and UNIX.

Richard T. Cederwall is interested in modeling turbulence in the planetary boundary layer; a topic he is pursuing in his Ph.D. dissertation research at Stanford University. He is also interested in atmospheric transport and diffusion phenomena at local and regional scales.

Stevens T. Chan has worked in the areas of fluid dynamics, thermal convection in liquid metals, and the atmospheric transport and diffusion of heavy gases. His recent research activities and interests include the development and applications of two- and three-dimensional computer programs for modeling incompressible flows, mesoscale atmospheric flows, and the atmospheric dispersion of heavy gases.

Hung-Neng (Steve) Chin is interested in the mesoscale aspects of convective storm dynamics, especially the representation of the dynamic and radiative effects of clouds in general circulation models and the coupling of cloud- and global-scale motions. His interests also include the regional impact of global climate change.

Chien-Hua (Cathy) Chuang is primarily interested in the microphysics of clouds and precipitation, the parameterization of these processes in mesoscale and global models, and the effects of pollutants on microphysics and consequently on climate. She is also interested in atmospheric electricity.

---

* See footnote on p.1.

Peter S. Connell is interested in the trace composition and photochemistry of the troposphere and stratosphere and in the related areas of gas phase kinetics and spectroscopy. He has modeled the effects of chlorofluorocarbons (CFCs) on the atmosphere and is involved with the Upper Atmospheric Research Satellite, to be launched by the space shuttle in 1991.

Stephen P. Cooper is interested in data communications and networking as applied to distributed computer applications.

Thomas G. Corsetti is interested in climate modeling and climate model analysis.

Curtis C. Covey is interested in the role of the oceans in climatic change. As part of the PCMDI, he is creating a database on ocean general circulation models and evaluating selected OGCMs for possible future model diagnosis and intercomparison. He is preparing to use an OGCM to examine the rate of global warming in response to human-produced greenhouse gases.

J. Daryl Crew is interested in developing application software involving applied mathematics and computer graphics.

Marvin H. Dickerson has been Deputy Division Leader of the Atmospheric and Geophysical Sciences Division since 1987. His research interests include atmospheric dispersion, emergency response to atmospheric releases of nuclear and toxic material, and atmospheric numerical modeling in general.

Jane E. Dignon is interested in the modeling of atmospheric chemical processes. Her research focuses on development of global trace gas emissions inventories from natural and anthropogenic sources, and the effect these emissions have on ambient trace gas concentrations and climate.

Robert S. Drach is interested in scientific database development, artificial intelligence, scientific programming, and applied mathematics.

Harold E. Eddleman is interested in supporting the atmospheric chemistry group's studies of smoke and black carbon with GRANTOUR and CCM1/GRANTOUR coupled mode.

Leslie L. Edwards is interested in numerical solutions of physics problems and has experience in compressible fluid dynamics, reactor safety, waste disposal, and detailed microphysics of the atmosphere. His current work is in the areas of atmospheric fallout phenomonology, pollutant transport, and predictor/corrector integration of measurements with models.

James S. Ellis is interested in satellite remote sensing of the Earth–atmosphere system and model evaluation.

K. Patrick Ellis is the Atmospheric Release Advisory Capability (ARAC) Meteorological Tower Coordinator, and in this capacity, oversees the purchasing, installation, and maintenance of meteorological towers at various ARAC Sites. As Atmospheric Studies in Complex Terrain (ASCOT) Coordinator, he oversees the purchasing, installation, and maintenance of ASCOT meteorological towers, and also performs tethersonde experiments, recording data for use by G-Division modelers.

Hugh W. Ellsaesser, a participating guest with G-Division, is interested in understanding the factors controlling terrestrial climate, air pollution, the ozone layer, the cycles and budgets of trace atmospheric species, and the elucidation of past cycles and trends of parameters bearing on these issues.

Donald L. Ermak is interested in the study of the atmospheric boundary layer, turbulence, and the atmospheric dispersion of denser-than-air and toxic gas releases.

Kevin T. Foster is interested in modeling of the boundary layer, especially as applied to operational emergency response; and the regional transport and diffusion of atmospheric pollutants.

Robert P. Freis is interested in several categories of computer science and computational physics: numerical modeling of physical processes, numerical analysis, user interface, numerical solutions of PDEs and ODEs, graphics, and visualization.

W. Lawrence Gates is interested in a broad range of subjects in atmospheric dynamics and numerical modeling, with a particular interest in the dynamics of climate, ocean-atmosphere modeling, the climatic effects of increased greenhouse gases, and climate model validation, diagnosis, and intercomparison.

Donald A. Garka is interested in computer system management, network management, and database systems.

Steven J. Ghan specializes, as a climate modeler, in the interaction between clouds, aerosols, and climate. He has investigated the "nuclear winter" hypothesis using general circulation models (GCMs) adapted to treat transport and removal of aerosols and their radiative impacts. More recently, he has used a GCM to evaluate the cloud liquid water feedback on climate sensitivity to simulate the global distribution of cloud condensation nuclei using an aerosol transport model.

Yolanda G. Glaeser is interested in effective management of data and communications for emergency response and in efficient procedures for running models in support of complex assessment studies.

Keith E. Grant is interested in radiation transport, especially modeling and parameterization of radiative physics and photochemistry. He is also interested in atmospheric data analysis and display.

George D. Greenly, Jr. is interested in the modeling of transport and dispersion processes in the atmospheric boundary layer.

Philip M. Gresho is interested in numerical methods in general and finite element methods for fluid mechanics in particular. He is especially interested in the physics and mathematics of viscous incompressible flow and its numerical simulation. Buoyancy-coupled flows is another area of interest.

Stanley L. Grotch is interested in the development and application of statistics and graphics to meteorological data with particular emphasis on greenhouse-induced climate change.

Paul H. Gudiksen is interested in nuclear and toxic chemical emergency response modeling. His research focuses on boundary layer modeling in complex terrain, analysis of meteorological and tracer measurements, and nuclear accident assessments.

Ted F. Harvey is an expert in local and global fallout and rainout. He is interested in integration of measurements into emergency response models; optimization of sampling networks; nuclide transport from the reactor core to and through the environment and on to man; nuclear waste management; numerical model inversion; probabilistic risk analysis; and stochastic modeling.

Anthony T. Hoang is interested in VAX- and UNIX-based system management and administration.

John K. Hobson is interested in numerical analysis, fluid dynamics, and computing environments.

Douglas E. Kinnison is interested in global atmospheric chemical and physical processes. His research focuses on trace gas emissions from natural and anthropogenic sources and on the effect of these emissions on trace gas concentrations (e.g., stratospheric ozone distribution) and climate. He has researched the trends in ozone from 1950 to present using the LLNL chemical-radiative-transport model of the troposphere and stratosphere. In addition, he is studying the effect on global ozone distributions from emissions of NO_x by proposed fleets of High Speed Civil Transports (HSCTs).

Ronald P. Koopman is interested in planning and conducting heavy-gas field studies and in modeling the dispersion, chemical, and physical properties of these gases. This work is focused on defining the hazards associated with heavy toxic gases and on improving the safety of their transport and storage.

Rolf Lange is interested in atmospheric fluid dynamics, specifically, turbulent diffusion of atmospheric pollutants. His emphasis is on numerical modeling of the transport and on diffusion of pollutants in the planetary boundary layer.

Leonard A. Lawson is interested in numerical methods with respect to atmospheric transport and diffusion models.

Robert L. Lee is interested in the development and application of numerical models for the atmospheric boundary layer, particularly those that are based on the finite element method. He has also developed finite element techniques for solving the Maxwell equations. His current activities include radiation parameterization for finite element-based, atmospheric, boundary layer models, and higher-order turbulence modeling with application to flows around buildings.

John M. Leone, Jr. is interested in the numerical simulation of incompressible fluid flows, with special emphasis on mesoscale meteorological flows. He has concentrated his efforts on the application of finite element methods to the simulation of planetary boundary layer flows driven by interactions between the atmosphere and local complex topography.

Ambrosio R. (Beb) Licuanan is interested in UNIX Local Area Network (LAN) management, autotasking large application codes, and interactive graphic .nalysis tools.

Michael C. MacCracken has been Division Leader of the Atmospheric and Geophysical Sciences Division since 1987. His research focuses on the study of climate change, with interests including paleoclimate variations, greenhouse gas-induced change, and changes induced by volcanic aerosols, soot, and nuclear smoke.

Rose C. McCallen is interested in the numerical modeling of fluid flow. Currently, she is developing a model for predicting the turbulent flow around buildings using a large-eddy simulation approach. This research serves the dual purpose of supplying LLNL with a tool for accurately predicting the near-field dispersion of ground spill and stack pollutants and of fulfilling her research requirements for a Ph.D. from U. of Calif., Davis.

Mary Ann Mansigh is interested in software tool prototyping and development for efficient computer model analysis. She also has interests in chemical-radiative-transport modeling.

Mary K. Meyer is interested in surface processes and how they are parameterized in general circulation models. She is also interested in the biosphere and how changes in it affect climate.

Connee S. Mitchell is interested in boundary layer meteorology and atmospheric dispersion modeling, with emphasis on application to emergency response and preparedness.

Robert L. Mobley is interested in fluid dynamical modeling, graphics, networking, very large database methods, and parallel computing.

Charles R. Molenkamp is a cloud physicist interested in cloud modeling, parameterization of microphysics, precipitation scavenging, and parameterization of scavenging microphysics. He has done numerical modeling of fog and cloud formation in mesoscale regions, and he is interested in interactions between clouds and radiation.

R. Miki Moore is interested in the analysis, design, and implementation of computer modeling systems on UNIX-based Sun workstations.

Louise K. Morris is the computer scientist assigned to the Liquefied Gaseous Fuels (LGF) Program where she develops software tools for maintaining LGF Program databases, for analyzing these data, and for preparing input to technical reports on experimental results.

John S. Nasstrom is interested in the development and application of real-time dispersion modeling systems, automated model parameter preprocessing, model validation, boundary layer meteorology, and atmospheric diffusion.

Joyce E. Penner is interested in modeling of global tropospheric chemistry and its interactions with climate. Her current emphasis is on modeling the nitrogen and sulfur cycles. She is also developing the capability to predict aerosol concentrations, tropospheric ozone, and aerosol–cloud interactions.

Linda G. Peters is interested in developing and applying numerical models to simulate dispersion and deposition of radionuclides. Her current research focuses on probabalistic risk analysis and particle model development.

Thomas J. Phillips is interested in investigating climate models' predictions (on seasonal to decadal time scales) when driven by satellite-derived observations of surface temperatures over the oceans/sea ice.

Gerald L. Potter is interested in climatic feedback mechanisms, regional climate change, cloud radiative forcing, and the general climatic effects of greenhouse warming.

Howard C. Rodean is a recent LLNL retiree and a Participating Guest in the Mesoscale Modeling and Dense Gas Dispersion Group. He has contributed to the development of the FEM3A model for gas transport and dispersion, particularly the material phase-change submodel. He has extended this phase-change work to a generalized structure for modeling complex material behavior. His present major effort is in applying the Langevin (random walk) model for turbulent dispersion to the ADPIC model used in the ARAC system.

Daniel J. Rodriguez is interested in techniques for numerically modeling the atmospheric transport and diffusion of trace species over continental to hemispheric distances. His modeling is geared toward providing a real-time response capability.

Leonard C. Rosen has a wide range of interests in atmosheric physics. He has recently performed calculations on Mie scattering and laser– aerosol interactions. Currently, he is performing research in radiation theory—the modeling of IR and UV with biological consequences (action spectra).

Walter W. Schalk, III is interested in the use of atmospheric models for real-time assessment of hazardous material accidents, with a special interest in accidents occurring in severe weather (e.g., thunderstorms, hurricanes). He is also involved with the assessments for Safety Analysis Reports and Environmental Impact Statements.

Charles S. Shapiro is a G-Division consultant and professor of physics, San Francisco State University. His primary research interest is in radioactive contamination from weapons, reactors, and other nuclear fuel cycle facilities. He has participated in G-Division's "nuclear winter" program and in the SCOPE-ENUWAR study; he is now focusing on the study of pathways of radionuclides through the environment and is actively participating in a new SCOPE international study on this subject titled "RADPATH."

Debra R. Sparkman is interested in the design and implementation of UNIX computer systems including object-oriented methods, requirements development, C programming language, X-windowing environment and hardware components.

Kenneth R. Sperber is interested in the simulation of interannual variability with coupled ocean-atmosphere global climate models. His research has shown that coupled models are useful tools for the study of time-dependent phenomena in addition to their current use for studying equilibrium properties of climate.

John L. Stout is interested in the visual display of simulated data from the general circulation models for the best utilization of that data. He is developing techniques for computer-generated database queries to browse large data sets for sensitive features of both observed and simulated data for this purpose.

Thomas J. Sullivan is interested in the application of atmospheric models to real-time consequence assessment of hazardous material accidents; primary emphasis is on the local to regional scale but extends also to the global scale. A significant part of his interests focus on the integration of evolving computer technologies, databases, and communications with advanced dispersion models to support emergency-response decision processes.

Denise A. Sumikawa is interested in computer user interfaces and software engineering methodologies.

Karl E. Taylor is interested in a wide range of scientific issues related to global climate. His recent research activities have included climate model studies of the effects of clouds on climate and climate change, and the potential importance of sea-ice albedo feedback.

Sandra S. Taylor is interested in design and development of computer systems, software engineering, project management, and software development tools.

David P. Turner is interested in numerical methods, parallel processing, and graphics.

Charles R. Veith is interested in real-time processing of meteorological data, systems availability, and the numerous elements of building and maintaining reliable emergency response capabilities for atmospheric releases of hazardous materials.

Hoyt Walker is interested in computer cartography, geographic information systems, and the characteristics of spatial databases. He is also interested in the application of these fields to spatial modeling and emergency response.

John J. Walton is interested in modeling global-scale atmospheric transport and removal processes and in the inclusion of chemical reactions in these models.

Jon G. Welch is interested in PC workstations for ARAC site systems/hardware and communications for ARAC users.

Conrad A. Wilgus is interested in numerical modeling, languages, software engineering, and scientific visualization.

Carolyn D. Wimple is interested in computer graphics standards; specifically GKS, COM, IGES/PDES, and geographical information systems. She is also interested in the X-windowing system and promoting the use of software engineering methodologies.

Donald J. Wuebbles is interested in interactions of atmospheric chemical, radiative, and dynamical processes; modeling of global atmospheric chemical and physical processes; tracer transport in the troposphere and stratosphere; perturbation to the global atmosphere; and changes in atmospheric composition affecting climate.

Appendix B. University, Laboratory, and Institute Interactions by Sponsor

DOE

Environmental Consequences of Nuclear War (DP)

Desert Research Institute and University of Nevada (John Hallet), *estimation of smoke/cloud interactions*

University of Utah (Magdy Iskander), *optical properties of large fractal aggregates*

University of Washington (Lawrence Radke), *modeling of aerosol aging experiments and cloud/aerosol interactions*

Trace Gas Policy (EH)

Goddard Space Flight Center (Dave Kratz), *atmospheric radiation modeling*

ASCOT Modeling and Field Studies (OHER)

National Center for Atmospheric Research (Terry Clark), *mesoscale modeling*

NOAA Wave Propagation Laboratory (William Neff), *local scale flows in complex terrain*

Carbon Dioxide Program Management (OHER)

Ocean Research Consultants (Tim Barnett), *detection of climate change*

State Hydrological Institute, Leningrad (M. E. Budyko), U.S./U.S.S.R. report on *Prospects for Future Climate*, Working Group VIII.

University of California Institute for Collaborative Research in Global Climate Modeling (Richard Somerville, University of California, San Diego, and Check Keller, Los Alamos National Laboratory), *global climate modeling*

University of East Anglia (T. M. L. Wigley), *rate of climate change, intercomparison of simplified ocean models*

Climate Linkages (OHER)

Lawrence Berkeley Laboratory (Tica Novakov), *experimental studies of particle scavenging; global carbonaceous aerosol modeling and measurements*

University of California, Berkeley (Van Carey), *hydrodynamic modeling of particle scavenging in a cloud chamber*

Climate Modeling (OHER)

University of California, Davis (Bryan Weare and Peter Gleckler), *zonally-averaged climate modeling*

University of California, San Diego (Richard Somerville and Peter Norris), *clouds and climate*

Program for Climate Model Diagnosis and Intercomparison (OHER)

European Centre for Medium Range Weather Forecasts, Reading, U.K. (Dave Burridge, Klaus Arpe, and Jean-Jacques Morcrette), *climate model intercomparisons*

National Center for Atmospheric Research (Warren Washington, Robert Chervin, and Julia Slingo), *climate model intercomparisons*

Naval Post-graduate School (Robert Chervin and Albert Semtner, Jr.), *simulations of ocean circulation and heat transport as a function of resolution*

Regional Modeling (OHER)

University of Colorado (Robert L. Sani), *fluid mechanics, applied mathematics, finite elements*

Trace Gases and Climate (OHER)

University of California, Berkeley (Harold Johnston), *trace gas-chemistry interactions*

University of Maryland (Robert Ellingson), *radiation model intercomparison*

NASA

Two-Dimensional Radiative-Transport-Kinetics Model

E.I. Dupont Nemoures & Co. (Don Fisher), *ozone depletion potential*

National Oceanic and Atmospheric Administration (Alvin J. Miller), *ozone-temperature analyses*

National Oceanic and Atmospheric Administration (John DeLuisi), *ozone data comparisons*

University of Chicago (George Tiao), *statistical analysis of ozone and temperature trends*

University of Wisconsin (Greg Reinsel), *statistical analysis of ozone and temperature trends*

Studies of the Global Sulfur Cycle

Chico State University (Greg Taylor), *modeling of gas phase chemical oxidation and aqueous conversion*

San Jose State University (Sonia Kreidenweis-Dandy), *sulfur microphysics and chemistry*

Scripps Institution of Oceanography (David Erickson), *simulation of the global sulfur cycle*

Industrial Organizations

FEM3A Simulation of LNG vapor barrier experiments (GRI)

University of Arkansas (Jerry Havens and Tom Spicer), *numerical simulations, turbulence modeling*

Lawrence Livermore National Laboratory

Global Chemistry Modeling (IR&D)

State University of New York Stony Brook (Sultan Hameed), *global modeling of nitrogen oxide chemistry*

University of California, Davis (Cynthia S. Atherton, graduate student), *global atmospheric chemistry*

University of Miami, (Dennis Savoie and Joe Prospero), *nitrate and surface concentrations at remote sites*

Yale University (William Gravstein), *model comparison with* ^{210}Pb *and* ^{7}Be *measurements*

Ocean Response to Global Warming (IR&D)

Scripps Institution of Oceanography and Max Planck Institute for Meteorology (Tim Barnett, Arthur Miller, and Josef Oberhuber), *oceanic GCM simulations of warming rate due to increasing greenhouse gases*

Atmospheric and Geophysical Sciences Division

NCAR (Robert Dickinson), *calculate upper limit to sea ice albedo feedback to global warming*

San Francisco State University (Charles S. Shapiro), *radiological impact of large scale releases of nuclear material*

Appendix C. Fiscal Year 1989 Funding

Work for Programs Funded by DOE and LLNL

Title	Sponsor	FY89 Budget (K$)	Principal Investigator	Objective
DOE				
ARAC	EH	1500	T. Sullivan	Develop and operate the ARAC service for DOE, DOD, and other federal agencies
ARAC Equipment Funds	EH	450	T. Sullivan	For ARAC center equipment
Data Preservation	FE	18	R. Koopman	Transfer LGF dense gas dispersion data and data reduction programs to VAX
LGF Baseline	FE	154	R. Koopman	LGF baseline support for test facility
ARAC Naval Reactor	NR	243	T. Sullivan	Provide ARAC service to DOE NR sites
NR Site Systems	NR	302	T. Sullivan	For purchase of NR ARAC Site system equipment
Model Improvement	OAC	200	P. Gudiksen	To improve long-range diagnostic atmospheric dispersion models
ASCOT Field Support	OHER	267	P. Gudiksen	Help plan and participate in ASCOT field studies designed to evaluate mesoscale models in complex terrain
ASCOT Modeling	OHER	297	J. Leone	Develop and test complex terrain atmospheric boundary layer models and apply to emergency response
Climate Management Support	OHER	300	M. MacCracken	Assist the DOE carbon dioxide program with scientific reviews and interactions
Climate Modeling	OHER	320	K. Taylor	Conduct modeling studies investigating model sensitivity and rate of change
Clouds and Radiation	OHER	230	J. Ellis	Intercompare radiation models for clear and cloudy sky conditions
General Circulation Model Intercomparison	OHER	400	G. Potter	Organize an international intercomparison of GCM responsiveness to perturbations
Program for Climate Model Diagnosis and and Intercomparison	OHER	2000	W. L. Gates	Conduct model intercomparison and diagnostic studies
Regional Modeling	OHER	89	J. Leone	Refine finite element techniques as they relate to mesoscale boundary layer models
Trace Gases and Climate	OHER	350	D. Wuebbles	Evaluate the interactions of atmospoheric chemistry and climate
ARAC ARG Support	OMA	150	T. Sullivan	Support of DOE's Accident Response Group (ARG)

Work for Programs Funded by DOE and LLNL (Continued)

Title	Sponsor	FY80 Budget (K$)	Principal Investigator	Objective
LLNL				
Environmental Consequences of Nuclear War	DP	1011	J. Penner/ S. Ghan/ M. Bradley/ D. Wuebbles	Assessment of potential global effects and perturbations to the atmosphere from a large-scale nuclear war
Fallout Research	DP	287	T. Harvey	Maintain state-of-the-art fallout prediction capabilities at LLNL
Model System Integration	DP	90	P. Gudiksen	Development of long range atmospheric dispersion modeling capabilities
Global Modeling	IR&D	75	C. Covey	Improvement and application global general circulation model for climate studies
Tropospheric Chemistry	IR&D	175	J. Penner	Development of tropospheric chemistry model, initially of nitrogen oxide species
InCoR Support	Physics Dept	25	J. Penner	Support of post-doc fellow under UC Institutional Cooperative Research program with Scripps and LANL to do research on tropospheric chemistry
Ocean Model Evaluation	Physics Dept	25	M. MacCracken	Support for graduate student research at Lamont-Doherty Geological Observatory for research on ocean circulation

Work for Programs Funded by Other Agencies and Organizations

Title	Sponsor	FY89 Budget (K$)	Principal Investigator	Objective
Federal				
ARAC DOD Exercises	DNA	26	T. Sullivan	Participate in DOD emergency response exercises
Environmental Consequences of Nuclear War	DNA	200	J. Penner	Development and application of microphysical interactions of aerosol, drops, and hydrometeors
ARAC	DOD	1604	T. Sullivan	Develop and operate the ARAC service for DOE, DOD, and other federal agencies
Crystal Growth	DOD	21	P. Gresho	Develop numerical simulation techniques for large crystal growth applications
Data Preservation	EPA	30	R. Koopman	Transfer LGF dense gas dispersion data and data reduction programs to VAX
Global Change Influences	EPA	224	J. Penner/ D. Wuebbles	Assess state of knowledge, identify key sensitivities, and perform research needed to reduce uncertainties and provide needed knowledge on trends in atmospheric species and potential impacts on atmospheric chemistry and climate
Modeling for EPA Site	EPA	20	T. Sullivan	Analyze six incident scenarios, utilizing ARAC models and provide EPA with written and graphical projections
UARS (Definition Phase)	NASA	120	D. Wuebbles	Provide support to UARS project during advanced definition phase and finalize details of theoretical investigation requirements
Zonal Averaged Chemical Transport Model of the Troposphere and Stratosphere	NASA	215	D. Wuebbles	Develop and apply state-of-the-art, time-dependent 2-D model for studying coupling of chemical, radiative, and dynamical processes in the atmosphere; maintain and further develop 1-D model
ARAC NRC Support	NRC	30	T. Sullivan	Training and drill assistance to the NRC and ongoing software interface update, maintenance, and testing services

Work for Programs Funded by Other Agencies and Organizations (Continued)

Title	Sponsor	FY89 Budget (K$)	Principal Investigator	Objective
<u>Federal (continued)</u>				
Continuation of FEM3A Transfer to CRDEC	USA	50	H. Rodean/ S. Chan	Consulting and training of CRDEC personnel on use of FEM3A computer code at Aberdeen Proving Grounds
Model Integration	USAF	200	P. Gudiksen/ D. Rodriguez	Evaluation of long-range models and integration of models with databases and computational system for USAF applications
Validation Study	USAF	34	D. Ermak	Development of methodology for evaluating dense gas dispersion models
ARAC Naval Shipyards (NSY) and Fleet HQ	USN	574	T. Sullivan	Provide ARAC service, training, and exercises to selected NSY and Fleet HQ
<u>Non-Federal</u>				
HF Data Report	AMOCO	30	R. Koopman	Complete data report for hydrogen fluoride (HF) test series (AMOCO through DOE)
SLAB Heavy-Gas Dispersion Model	API	80	D. Ermak	Produce an improved version of SLAB code, write user's manual, and implement a vertical jet source capability in SLAB code
FEM3 Simulations of LNG Field Tests	GRI & GRI/DOT	136	S. Chan	FEM3 computer code will be used to simulate up to three LNG vapor barrier verification tests. Complete data and analysis reports for LNG test series
Mobil HF Archive and Report	Mobil R&D	156	R. Koopman	Complete data and analysis report for HF water spray test series.
UK ARAC Support	UK/MOD	40	G. Greenly	Develop customized ARAC software, establish ARAC link with UK, and participate in annual exercise with UK

Appendix D. Special Outside Staff Activities

Michael M. Bradley: Co-chairman for Cloud Physics, Interagency Lightning Threat Warning Working Group; member, AFOSR Atmospheric Sciences Review Panel, Commission on Physical Sciences, Mathematics, and Applications, National Research Council; staff Weather Officer (lieutenant colonel), Air Weather Service, U.S. Air Force Reserve

Curtis C. Covey: Member, NAS Committee on Global Change, Subgroup on Ocean–Atmosphere Models

Marvin H. Dickerson: Member, DOE Subcommittee on Dose Assessment; consultant for the International Atomic Energy Agency in the area of emergency preparedness; ARM model coordinator

Jane E. Dignon: Member, International Global Atmospheric Chemistry Program Committee for Development of Global Emissions Inventories; U.S.–P.R.C. Cooperative Program in Atmospheric Chemistry

W. Lawrence Gates: Chairman, Working Group on Numerical Experimentation, World Climate Research Programme; lead author, Working Group I, Intergovernmental Panel on Climate Change, World Meteorological Organization; member, Scientific Advisory Committee, Climate Systems Modeling Program, University Corporation for Atmospheric Research; (founding) Editor, *Climate Dynamics*

George D. Greenly, Jr.: Chairman, Basic Sciences and Technology Division of the Air and Waste Management Association (AWMA); member, AB-3 Meteorology Committee of AWMA; American Meteorological Society Certified Consulting Meteorologist (CCM); observer, meteorology subpanel of the joint DOE/DOD/NASA Interagency Nuclear Safety Review Panel (INSRP); member, U.S.–U.K. Joint Working Group 29C (JOWOG 29C)

Philip M. Gresho: Editor, *International Journal for Numerical Methods in Fluids;* member of editorial board, *Communications in Applied Numerical Methods;* member of editorial board, *Latin American Journal of Heat and Mass Transfer;* Adjunct Professor, U. of Calif., Davis; member, National Fluid Dynamics Congress; member, Society for Industrial and Applied Mathematics (SIAM); member, American Physical Society (Division of Fluid Dynamics)

Paul H. Gudiksen: Member, ASCOT Program Planning and Advisory Panel; Chairman, Toxic Chemical Sampling Working Group of the DOE Subcommittee on Dose Assessment; member, Environmental Transport Group of U.S.–U.S.S.R. Joint Coordinating Committee for Civilian Nuclear Reactor Safety; scientific advisor to Indian Institute of Technology, New Delhi

Joseph B. Knox: Bluenose Panel Member; LLNL representative to Lawrence Berkeley Laboratory for Environmental Policy Center; LLNL representative to DOE-OHER Global Effects Research Committee; Director, National Institute for Global Environmental Change

Ronald P. Koopman: Scientific Advisor, DOE/Nevada, Liquefied Gaseous Fuels Spill Test Facility

Robert L. Lee: Member of editorial board, *International Journal for Numerical Methods in Fluids*

John M. Leone, Jr.: Member, American Meteorological Society Committee on the Meteorological Aspects of Air Pollution

Michael C. MacCracken: Principal Scientist for Climate Element of DOE CO_2 Research Program; Chairman, DOE Multi-Laboratory Climate Change Committee; U.S. Co-chair of Climate Project of U.S.–U.S.S.R. Working Group VIII; Associate Editor, *Journal of Climate;* Chairman, U.S.–Canada Technical Advisory Panel on Acid Precipitation Field Program and Model Verification; member, International Commission on Climate; member, EPA Technical Advisory Panel on Global Climate Change; member, Executive Committee, LANL LLNL Scripps Institute for Collaborative Research on Global Climate Modeling; Director, DOE CHAMMP (Computer Hardware, Advanced Mathematics, and Model Physics) program; co-author, ISCU-SCOPE ENUWAR report on nuclear winter research

Joyce E. Penner: Member, National Academy of Sciences Committee on Atmospheric Chemistry (1990–1993); member, California Air Resources Board Modeling Advisory Committee (1988–1992); thesis advisor for a student from U. of Calif., Davis

Gerald L. Potter: Member, Executive Committee of the Energy Research Supercomputer Users Group; member, U.S.–P.R.C. delegation on CO_2-induced climate change; leader, PCMDI participation in the Supercomputer High School Honors Program

Charles S. Shapiro: Member, Scientific Advisory Committee of ICSU–SCOPE–RADPATH study; Chairman, Atmospheric Transport Group of RADPATH; co-author, ICSU–SCOPE ENUWAR report on nuclear winter research

Thomas J. Sullivan: Member, DOE Subcommittee on Dose Assessment; member, DOE/FRMAC Evaluation and Assessment Working Group

Donald J. Wuebbles: Member, NASA Advisory Panel on High Speed Research Program; lead author, UNEP/WMO report on Scientific Assessment of Climate Change; lead author, UNEP/WMO report on Scientific Assessment of Stratospheric Ozone; member, DOE Multi-Laboratory Climate Change Committee; member, U.S.–U.S.S.R. Working Group VIII; member, ICMUA Working Group on Modeling of the Middle Atmosphere; member, IUGG Working Group on Solar Forcing

Appendix E. Publications

January 1988 through December 1989

Journal Articles, Books, and Book Chapters

Atherton, C. S. (1989), "Organic Nitrates in Remote Marine Environments: Evidence for Long Range Transport," *Geophysical Research Letters,* **16**, 1289–1292.

Atherton, C. S., and J. E. Penner (1988), "The Transformation of Nitrogen Oxides in the Polluted Troposphere," *Tellus,* **40B**, 380–392.

Broecker,[*] W. S. (1989), "Some Thoughts about the Radiocarbon Budget for the Glacial Atlantic," *Paleoceanography,* **4**, 213–220.

Broecker,[*] W. S. (1989), "The Salinity Contrast between the Atlantic and Pacific Oceans during Glacial Time," *Paleoceanography,* **4**, 207–212.

Broecker,[*] W. S., and T.-H. Peng[†] (1989), "The Cause of the Glacial to Interglacial Atmospheric CO_2 Change: A Polar Alkalinity Hypothesis," *Biogeochemical Cycles,* **3**, 215–239.

Cess,[*] R. D., G. L. Potter, J. P. Blanchet,[†] G. J. Boer,[†] S. J. Ghan, J. T. Kiehl,[†] H. Le Treut,[†] Z.-X. Li,[†] X.-Z. Liang,[†] J. F. B. Mitchell,[†] J.-J. Morcrette,[†] D. A. Randall,[†] M. R. Riches,[†] E. Roeckner,[†] U. Schlese,[†] A. Slingo,[†] K. E. Taylor. W. M. Washington,[†] R. T. Wetherald,[†] and I. Yagai[†] (1989), "Interpretation of Cloud-Climate Feedback as Produced by 14 Atmospheric General Circulation Models," *Science,* **245**, 513–516.

Chan, S. T., J. M. Leone, Jr., and R. L. Lee (1989), "A Hydrostatic Mesoscale Model Using Finite Element and Finite Difference Techniques," *Finite Element Analysis in Fluids,* T. J. Chung and G. R. Karr (Eds.), University of Alabama in Huntsville Press, 544–553.

Covey, C. C. (1988), "Atmospheric and Oceanic Heat Transport: Simulations versus Observations," *Climatic Change,* **13**, 149–159.

Covey, C. C. (1989), "Mechanisms of Climatic Change," *Global Climate Change: Human and Natural Influences,* S. F. Singer (Ed.), Paragon House, New York, NY.

Covey, C. C., and S. L. Thompson[†] (1989), "Testing the Effects of Ocean Heat Transport on Climate," *Global and Planetary Change,* **75**, 331–341.

DeLuisi,[†] J. J., D. U. Longenecker,[†] C. L. Mateer,[†] and D. J. Wuebbles (1989), "An Analysis of Northern Middle-Latitude Umkehr Measurements Corrected for Stratospheric Aerosols for 1979–1986," *Journal of Geophysical Research,* **94**, 9837–9845.

Derby, J. J., L. J. Atherton, and P. M. Gresho (1989), "An Integrated Process Model for the Growth of Oxide Crystals by the Czochralski Method," *Journal of Crystal Growth,* **97**, 792–826.

Dignon,[**] J., and S. Hameed[*] (1989), "Global Emissions of Nitrogen and Sulfur Oxides from 1860 to 1980," *Journal of the Air Pollution Control Association,* **39**, 180–186.

Edwards, L. L., and J. E. Penner (1988), "Potential Nucleation Scavenging of Smoke Particles over Large Fires; A Parametric Study," *Aerosols and Climate,* P. V. Hobbs and M. P. McCormick (Eds.), A. Deepak Publishing, Hampton, VA, 423–434.

Frei,[†] A., M. C. MacCracken, and M. I. Hoffert[†] (1988), "Eustatic Sea Level and CO_2," *Northeastern Environmental Science,* **7**, 91–96.

---

* Consultant or subcontractor

† Collaboration

** Affiliated graduate student or post-doctoral fellow.

Ghan, S. J. (1988), "Global Climatic Effects of a Nuclear War: An Interdisciplinary Problem," *Climate and Geo-Sciences,* A. Berger, S. Schneider, and J. Cl. Duplessy (Eds.), NATO ASI Vol. 285, Kluwer Academic Publishers, Dordrecht, The Netherlands, 315–319.

Ghan, S. J. (1989), "Unstable Radiative-Dynamical Interactions. Part I: Basic Theory," *Journal of Atmospheric Sciences,* **46**, 2528–2543.

Ghan, S. J. (1989), "Unstable Radiative-Dynamical Interactions. Part II: Expanded Theory," *Journal of Atmospheric Sciences,* **46**, 2544–2561.

Ghan, S. J., M. C. MacCracken, and J. J. Walton (1988), "The Climatic Response to Large Atmospheric Smoke Injections: Sensitivity Studies with a Tropospheric General Circulation Model," *Journal of Geophysical Research,* **93**, 8315–8337.

Ghan, S. J., J. E. Penner, and K. E. Taylor (1989), "Sulfur, Climate Change, and Cloud Albedos," *Nature,* **340**, 438.

Ghan, S. J., K. E. Taylor, J. E. Penner, and D. J. Erickson** (1989), "Model Test of the CCN-Cloud Albedo Climate Forcing," *Research Letters,* **17**, 607–610.

Gresho, P. M. (1989), "The Finite-Element Method in Viscous Incompressible Flows," *Lecture Notes in Engineering,* **43**, 148–191, Springer-Verlag, New York, NY.

Grotch, S. L. (1988), "Regional Intercomparisons of General Circulation Model Predictions and Historical Climate Data," DOE Technical Report, TR041 (DOE/NBB-0084).

Gudiksen, P. H. (1989), "Categorization of Nocturnal Drainage Flows within the Brush Creek Valley and the Variability of Sigma Theta in Complex Terrain," *Journal of Applied Meteorology,* **28**, 489–495.

Gudiksen, P. H., T. F. Harvey, and R. Lange (1989), "Chernobyl Source Term, Atmospheric Dispersion, and Dose Estimation," *Health Physics,* **57**, 697–706.

Gudiksen, P. H., and D. L. Shearer† (1989), "The Dispersion of Atmospheric Tracers in Nocturnal Drainage Flows," *Journal of Applied Meteorology,* **28**, 602–608.

Hameed,* S., and J. Dignon** (1988), "Changes in the Geographical Distributions of Global Emissions of NO_x and SO_x from Fossil Fuel Combustion Between 1966 and 1980," *Atmospheric Environment,* **22**, 441–449.

Hameed,* S., K. R. Sperber**, and R. D. Cess* (1989), "Genesis of the Southern Oscillation within the Atmosphere: Illustration with Global General Circulation Models," *Geophysical Research Letters,* **16**, 691–694.

Iskander,* M. F., H. Y. Chen,* and J. E. Penner (1989), "Optical Scattering and Absorption by Branched Chains of Aerosols," *Applied Optics,* **28**, 3083–3091.

Iskander,* M. F., H. Y. Chen,* and J. E. Penner (1989), "Scattering and Absorption by Elongated Aerosol Particles in the Resonance Frequency Range," *Aerosol Science and Technology,* **10**, 172–180.

Johnston,† H., D. E. Kinnison,** and D. Wuebbles (1989), "Nitrogen Oxides from High Altitude Aircraft: An Update of Potential Effects on Ozone," *Journal of Geophysical Research,* **94**, 16,351–16,363.

Koopman, R. P., D. L. Ermak, and S. T. Chan (1988), "Review of Recent Field Tests and Mathematical Modelling of Atmospheric Dispersion of Large Spills of Denser-Than-Air Gases," International Conference on Tropical Micro-Meteorology and Air Pollution, Delhi, India, February 15–19, 1988; *Atmospheric Environment,* **23**, 731–745.

Lange, R. (1989), "Transferability of a Three-Dimensional Air Quality Model between Two Different Sites in Complex Terrain," *Journal of Applied Meteorology,* **28**, 665–679.

Lee, R. L., and J. M. Leone, Jr. (1988), "A Modified Finite Element Model for Mesoscale Flows over Complex Terrain," *Computers and Mathematics with Applications,* **16**, 41–56.

Lee, R. L., and J. M. Leone, Jr. (1988), "Applications of a Three-Dimensional Finite Element Model to Mountain-Valley Flows," *Computational Methods in Flow Analysis,* **1**, Hiroshi Niki and Mutsuto Kawahara (Eds.), Okayama University of Science, Okayama, Japan, 365–372.

Lee, R. L., and N. K. Madsen (1989), "A Staggered-Grid Finite Element Solution Technique for the Maxwell's Equations in the Time Domain," *Wave Phenomena: Theoretical, Computational and Practical Aspects,* Springer-Verlag, New York, NY, 140–146.

Leone, J. M., Jr., and R. L. Lee (1989), "Numerical Simulation of Drainage Flow in Brush Creek, Colorado," *Journal of Applied Meteorology,* **28**, 530–542.

MacCracken, M. C. (1988), "The Environmental Effects of Nuclear War," *Nuclear Arms Technologies in the 1990s,* R. G. Lerner, D. Schroeer, and D. Hafemeister (Eds.), American Institute of Physics, Washington, DC, 1–18.

MacCracken, M. C., and S. J. Ghan (1988), "Design and Use of Zonally-Averaged Climate Models," *Physically-Based Modelling and Simulation of Climate and Climatic Change,* M. E. Schlesinger (Ed.), NATO ASI, Vol. 243, Kluwer Academic Publishers, Dordrecht, The Netherlands, 755–809.

MacCracken, M. C., and S. L. Grotch (1989), "The Detection of CO_2-Induced Climate Change," *Carbon Dioxide and Other Greenhouse Gases: Climatic and Associated Impacts,* R. Fantechi and A. Ghazi (Eds.), Commission of the European Communities, Directorate-General for Science, Research and Development, November 3–5, 1987, Brussels, Belgium.

Molenkamp, C. R. (1988), "Development of Low Level Coastal Flow Fields when Solar Radiation is Blocked by Smoke," *Aerosols and Climate,* Peter V. Hobbs and M. Patrick McCormick (Eds.), A Deepak, Hampton, VA, 459–470.

Molenkamp, C. R. (1989), "Numerical Simulation of Coastal Clouds when Solar Radiation is Blocked by Smoke," *Atmospheric Research,* **24**, 221–245.

Molenkamp, C. R. (1989), "Numerical Simulation of Coastal Flows when Solar Radiation is Blocked by Smoke," *Journal of Applied Meteorology,* **28**, 361–381.

Penner, J. E., P. S. Connell, D. J. Wuebbles, and C. C. Covey (1989), "Climate Change and its Interactions with Air Chemistry: Perspectives and Research Needs," *The Potential Effects of Global Climate Change on the United States,* J. B. Smith and D. A. Tirpak, (Eds.), U. S. Environmental Protection Agency, Washington, DC, EPA-230-05-89-056.

Penner, J. E., and C. R. Molenkamp (1989), "Predicting the Consequences of Nuclear War: Precipitation Scavenging of Smoke," *Aerosol Science and Technology,* **10**, 51–62.

Pittock,[†] A. B., T. P. Ackerman,[†] P. J. Crutzen,[†] M. C. MacCracken, C. S. Shapiro,[*] and R. P. Turco[†] (1989), *Environmental Consequences of Nuclear War: Volume 1, Physical and Atmospheric Effects,* Scope 28, Second Edition, John Wiley and Sons, Chichester, United Kingdom.

Rodriguez, D. J., and K. R. Peterson (1989), "Simulating the Venting of Radioactivity from a Soviet Nuclear Test," *Atmospheric Environment,* **23**, 953–958.

Shinn, J. H., R. T. Cederwall, F. J. Gouveia, and K. R. Chapman (1989), "Micrometeorology of Slope Flows in a Tributary Canyon during the 1984 ASCOT Experiment," *Journal of Applied Meteorology,* **28**, 569–577.

Walton, J. J., M. C. MacCracken, and S. J. Ghan (1988), "A Global-Scale Lagrangian Trace Species Model of Transport, Transformation, and Removal Processes," *Journal of Geophysical Research,* **93**, 8339–8354.

Wuebbles, D. J. (1989), "An Assessment Model for Atmospheric Composition," M. J. Prather (Ed.), NASA Conference Publication 3023.

Wuebbles, D. J. (1989), "On the Mitigation of Non-CO_2 Greenhouse Gases," *Greenhouse Mitigation,* A.E.S. Green (Ed.), American Society of Mechanical Engineers, New York, NY.

Wuebbles, D. J. (1989), "Two-Dimensional Intercomparison of Stratospheric Models," C. Jackman, R. Seals, and M. Prather (Eds.), NASA Conference Publication 3042.

Wuebbles, D. J. (lead author, Chapter 4, and contributing author, Chapter 3), and P. S. Connell (contributing author) (1989), *Scientific Assessment of Stratospheric Ozone: 1989, Volume I,* World Meteorological Organization, Global Ozone Research and Monitoring Project—Report No. 20.

Wuebbles, D. J., K. E. Grant, P. S. Connell, and J. E. Penner (1989), "The Role of Atmospheric Chemistry in Climate Change," *Journal of the Air Pollution Control Association,* **39**, 22–28.

Publications in Progress

Atherton, C. S. (1989), "Book Review of 'The Chemistry of Acid Rain: Sources and Atmospheric Processes,' R. W. Johnson and G. E. Gordon (Eds.)," Lawrence Livermore National Laboratory, UCRL-102401 Comments; submitted to *Bulletin of the American Meteorological Society.*

Atherton, C. S., and J. E. Penner (1988), "The Effects of Biogenic Hydrocarbons on the Transformation of Nitrogen Oxides in the Troposphere," Lawrence Livermore National Laboratory, UCRL-99755, Rev. 1; accepted by *Journal of Geophysical Research.*

Broyles,* A. A. (1989), "Bone Marrow Injury and the Gamma Ray Mortality for Man," Lawrence Livermore National Laboratory, UCRL-99459, Rev. 1; submitted to *Health Physics.*

Cederwall, R. T., and K. R. Peterson (1989), "Meteorological Modeling of Arrival and Deposition of Fallout at Intermediate Distances Downwind of the Nevada Test Site," Lawrence Livermore National Laboratory, UCRL-96150; accepted by *Health Physics.*

Cederwall, R. T., Y. E. Ricker, P. L. Cederwall, D. N. Homan, and L. R. Anspaugh (1989), "Measurements of Airborne Radionuclide Concentrations Near the Nevada Test Site from Atmospheric Testing," Lawrence Livermore National Laboratory, UCRL-96153; accepted by *Health Physics.*

Cess,* R. D., G. L. Potter, J. P. Blanchet,† G. J. Boer,† A. D. DelGenio,† M. Dequé,† V. Dymnikov,† V. Galin, W. L. Gates, S. J. Ghan, J. T. Kiehl, A. A. Lacis, H. Le Treut, Z.-X. Li, X.-Z. Liang, B. J. McAvaney,† V. P. Meleshko,† J. F. B. Mitchell,† J.-J. Morcrette,† D. A. Randall,† L. Rikus,† E. Roeckner,† J. F. Royer,† U. Schlese,† D. A. Sheinin,† A. Slingo,† A. P. Sokolov,† K. E. Taylor, W. M. Washington,† R. T. Wetherald,† I. Yagai,† and M.-H. Zhang (1989), "Intercomparison and Interpretation of Climate Feedback Processes in Eighteen Atmospheric General Circulation Models," *Journal of Geophysical Research,* (in press).

Chen,* H. Y., M. F. Iskander,* and J. E. Penner (1989), "An Empirical Formula for Electromagnetic Absorption by Fractal Aerosol Agglomerates," Lawrence Livermore National Laboratory, UCRL-100846; submitted to *Applied Optics.*

Chen,* H. Y., M. F. Iskander,* and J. E. Penner (1989), "Effects of Cloud Condensation on Electromagnetic Absorption," Lawrence Livermore National Laboratory, UCRL-101847; submitted to the *Journal of Atmospheric Sciences.*

Chen,* H. Y., M. F. Iskander,* and J. E. Penner (1989), "Light Scattering and Absorption by Fractal Agglomerates and Coagulations of Smoke Aerosols," Lawrence Livermore National Laboratory, UCRL-100084; accepted by *Journal of Modern Optics.*

Dignon,** J. (1989), "NO_x and SO_x Emissions from Fossil Fuels: A Global Distribution," submitted to *Atmospheric Environment.*

Ellingson,* R. G., J. S. Ellis, and Y. Fouquart† (1988), "The Intercomparison of Radiation Codes in Climate Models (ICRCCM): Longwave Results," *Journal of Geophysical Research,* (in press).

Ellsaesser, H. W. (1989), "A Different View of the Climatic Effect of CO_2—Updated," Lawrence Livermore National Laboratory, UCRL-87940; submitted to *Atmosfera.*

Erickson,** D. J., III, S. J. Ghan, and J. E. Penner (1989), "Global Ocean-to-Atmosphere Dimethylsulfide Flux," Lawrence Livermore National Laboratory, UCRL-100441; *Journal of Geophysical Research,* (in press).

Fisher,† D. A., C. H. Hales,† D. L. Filkin,† M. K. W. Ko,† N. D. Sze,† P. S. Connell, and D. J. Wuebbles (1989), "Ozone Depletion Potentials for Chloroflurocarbons and Possible Replacements," Lawrence Livermore National Laboratory, UCRL-102274; submitted to *Nature.*

Foley,** J. A., K. E. Taylor, and S. J. Ghan (1989), "Planktonic Dimethylsulfide and Cloud Albedo: An Estimate of the Feedback Response," Lawrence Livermore National Laboratory, UCRL-100732; *Climatic Change* (in press).

Gates, W. L. (1989), "The Quest for Reliable Regional Scenarios of Climate Change," *Global Climate Change and its Effects on California,* (Proceedings of a conference at the University of California, Davis, June 1989), University of California Press, 10 pp. (in press).

Ghan, S. J. (1989), "Chronic Climate Effects of Nuclear War," Lawrence Livermore National Laboratory, UCRL-101737; *Atmospheric Environment* (in press).

Gresho, P. M. (1988), "Comments on 'A Conjugate-Residual FEM for Incompressible Viscous Flow Analysis,' by Eguchi, G. Yagawa, and L. Fuchs," submitted to *Computational Mechanics.*

Gresho, P., and S. T. Chan (1989), "On the Theory of Semi-Implicit Projection Methods for Viscous Incompressible Flow and its Implementation via a Finite Element Method that Introduces a Nearly-Consistent Mass Matrix, Part 1: Theory," Lawrence Livermore National Laboratory, UCRL-101222, Rev. 1, Pt. 1; submitted to *International Journal for Numerical Methods in Fluids.*

Gresho, P., and S. T. Chan (1989), "On the Theory of Semi-Implicit Projection Methods for Viscous Incompressible Flow and its Implementation via a Finite Element Method that Introduces a Nearly-Consistent Mass Matrix, Part 2: Implementation," Lawrence Livermore National Laboratory, UCRL-101222, Rev. 1, Pt. 2; submitted to *International Journal for Numerical Methods in Fluids.*

Grotch, S. L. (1989), "An Intercomparison of General Circulation Model Predictions of Regional Climate Change," Lawrence Livermore National Laboratory, UCRL-102793; submitted to *Journal of Climate Dynamics* .

Gudiksen, P. H., T. F. Harvey, and R. Lange (1989), "Chernobyl Source Term, Atmospheric Dispersion, and Dose Estimation," Lawrence Livermore National Laboratory, UCRL-98235, Rev. 3; submitted to *Health Physics.*

Iskander,* M. F., H. Y. Chen,* and J. E. Penner (1989), "Light Scattering and Absorption of Fractal Agglomerates of Smoke Aerosols," accepted by *Proceedings of the 1989 SBMO International Microwave Symposium,* July 24–27, 1989, Sao Paulo, Brazil.

Kreidenweis,† S., J. E. Penner, F. Yin,† and J. H. Seinfeld† (1989), "The Effects of Dimethylsulfide upon Marine Aerosol Concentrations," Lawrence Livermore National Laboratory, UCRL-102415; submitted to *Atmospheric Environment.*

Lacis,[†] A. A., D. J. Wuebbles, and J. A. Logan[†] (1989), "Radiative Forcing of Global Climate Changes in the Vertical Distribution of Ozone," Lawrence Livermore National Laboratory, UCRL-100715; *Journal of Geophysical Research* (in press).

Maslinak,[†] M. K., R. L. Sani*, and P. M. Gresho (1989), "An Isoparametric Element Stokes Flow Test Problem," submitted to *Communications in Applied Numerical Methods.*

Ng, Y. C., L. R. Anspaugh, and R. T. Cederwall (1989), "ORERP Internal Dose Estimates for Individuals," Lawrence Livermore National Laboratory, UCRL-96128; accepted by *Health Physics.*

Penner, J. E. (1989), "Cloud Albedo, Greenhouse Effects, Atmospheric Chemistry, and Climate Change," Lawrence Livermore National Laboratory, UCRL-99928, Rev. 1; invited feature article, *Journal of the Air and Waste Management Association.*

Penner, J. E., C. S. Atherton, J. Dignon,** S. J. Ghan, J. J. Walton, and S. Hameed* (1989), "Tropospheric Nitrogen: A Three-Dimensional Study of Sources, Distribution, and Deposition," Lawrence Livermore National Laboratory, UCRL-102183, Rev. 1; submitted to *Journal of Geophysical Research.*

Radke,[†] L. F., A. S. Ackerman,[†] J. H. Lyons,[†] D. A. Hegg,[†] P. V. Hobbs,[†] and J. E. Penner (1989), "Effects of Aging on the Smoke from a Forest Fire: Implications for the Nuclear Winter Hypothesis," submitted to the *Journal of Geophysical Research.*

Rodean, H. C. (1989), "A Structure for Models of Hazardous Materials with Complex Behavior," Lawrence Livermore National Laboratory, UCRL-100928, Rev. 1; accepted by *Atmospheric Environment.*

Rosen, L. C., and J. Ipser* (1989), "Scattering of Ground Based Lasers by Aerosols in an Atmosphere with Enhanced Particle Content," Lawrence Livermore National Laboratory, UCRL-100442, accepted by *Atmospheric Environment.*

Shirley,[†] J. H., K. R. Sperber,** and R. W. Fairbridge[†] (1989), "Sun's Inertial Motion and Luminosity," *Solar Physics,* (in press).

Taylor, K. E., and M. C. MacCracken (1989), "Projected Effects of Increasing CO_2 and Trace Gases on Climate," Lawrence Livermore National Laboratory, UCRL-100228; *American Society of Agronomy* (in press).

Reports and Proceedings

Bradley, M. M., K. R. Peterson, and D. J. Rodriguez (1988), "Three-Dimensional Numerical Modeling of Smoke Injections from Large Fires in the Early Post-Nuclear-Exchange Environment," Lawrence Livermore National Laboratory, UCRL-99562; in the *Proceedings of the Cloud Impacts on DOD Operations and Systems 1988 Workshop,* Naval Surface Warfare Center, White Oak, Maryland, October 18–20, 1988.

Chan, S. T. (1988), "FEM—A Finite Element Model for the Simulation of Gas Transport and Dispersion: User's Manual," Lawrence Livermore National Laboratory, UCRL-21043.

Chan, S. T., H. C. Rodean, and R. T. Cederwall (1989), "Numerical Simulation of Dense-Gas Dispersion over Water, Obstacles, and Sloping Terrain," Lawrence Livermore National Laboratory, UCRL-21211.

Chan, S. T., H. C. Rodean, R. T. Cederwall, and R. E. Meyers[†] (1989), "Numerical Simulation of Dense-Gas Dispersion in the Shoreline Environment," Lawrence Livermore National Laboratory, UCRL-100030; in the *Proceedings of the 1989 JANNAF Safety & Environmental Protection Sub-committee Meeting,* San Antonio, TX, April 3–7, 1989.

Connell, P. S., K. E. Grant, and D. J. Wuebbles (1988), "Aspects of CFC Relative Ozone Destruction Efficiencies Determined in the LLNL 2-D Model," Lawrence Livermore National Laboratory, UCRL-97987; in the *Proceedings of the 1988 International Quadrennial Ozone Symposium,* Göttinger, Federal Republic of Germany, August 8–13, 1988.

Connell, P. S., and D. J. Wuebbles (1989), "Evaluating CFC Alternatives from the Atmospheric Viewpoint," Lawrence Livermore National Laboratory, UCRL-99927, Rev. 1; Air and Waste Management Association paper 89-5.7.

Covey, C. (1988), "Thermal Energy Transport in CCM1," Lawrence Livermore National Laboratory, UCID-21557.

Dickerson, M. H., and D. L. Ermak (1988), "The Evaluation of Emergency Response Trace Gas and Dense-Gas Dispersion Models," Lawrence Livermore National Laboratory, UCRL-99348.

Dickerson, M. H., and K. T. Foster (1989), "Utilization of Dose Assessment Models to Facilitate Off-Site Recovery Operations for Accidents at Nuclear Facilities," Lawrence Livermore National Laboratory, UCRL-101842.

Dickerson, M. H., and T. J. Sullivan (1988), "The Atmospheric Release Advisory Capability (ARAC): A Federal Emergency Response Capability," Lawrence Livermore National Laboratory, UCRL-98435.

Edwards, L. L. (1989), "Condensation Growth and Nucleation Scavenging over Large Fires," Lawrence Livermore National Laboratory, UCID-21785.

Edwards, L. L. (1989), "Simulations of Cloud Condensation Droplet Nucleation and Growth," Lawrence Livermore National Laboratory, UCID-21633.

Edwards, L. L., and J. E. Penner (1988), "A Parametric Study of Condensation Growth and Nucleation Scavenging over Large Fires," Lawrence Livermore National Laboratory, UCRL-97422; in the *Proceedings of the 12th International Conference on Atmospheric Aerosols and Nucleation,* Vienna, Austria, August 22–27, 1988.

Ellsaesser, H. W. (1989), "Atmospheric Carbon Dioxide and the Climate Record," Lawrence Livermore National Laboratory, UCRL-100954; 5–18 in the *Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop,* Asilomar, CA, March 5–8, 1989.

Ermak, D. L. (1988), "Field Validation of Dispersion Models for Dense-Gas Releases," Lawrence Livermore National Laboratory, UCRL-98139, in the *Proceedings of the 17th International Technical Meeting on Air Pollution Modeling and Its Applications,* Cambridge, United Kingdom.

Ermak, D. L. (1988), "SLAB: A Denser-Than-Air Atmospheric Dispersion Model," Lawrence Livermore National Laboratory, UCRL-99822.

Ermak, D. L. (1989), "A Description of the SLAB Model," Lawrence Livermore National Laboratory, UCRL-100028.

Ermak, D. L., R. Chapman, H. C. Goldwire, Jr., F. J. Gouveia, and H. C. Rodean (1988), "Heavy Gas Dispersion Test Summary Report," Lawrence Livermore National Laboratory, UCRL-21210.

Ermak, D. L., and M. H. Merry* (1988), "A Methodology for Evaluating Heavy-Gas Dispersion Models," Lawrence Livermore National Laboratory, UCRL-21025.

Ermak, D. L., H. C. Rodean, R. Lange, and S. T. Chan (1988), "A Survey of Denser-Than-Air Atmospheric Dispersion Models," Lawrence Livermore National Laboratory, UCRL-21024.

Ghan, S. J. (1989), "Simplified Climate Models: Rationale and Design," Lawrence Livermore National Laboratory, UCRL-100817; Short Course on Development of Zonally-Averaged Models of the Atmosphere, University of Louvain-la-Neuve, Belgium, April 17–May 15, 1989.

Gresho, P. M. (1988), "Modification of FEM3 to Ensure Mass Conservation," Lawrence Livermore National Laboratory, UCID-21280.

Gresho, P. M., and S. T. Chan (1988), "Semi-Consistent Mass Techniques for Solving the Incompressible Navier-Stokes Equations," Lawrence Livermore National Laboratory, UCRL-99503.

Gresho, P. M., and S. T. Chan (1988), "Solving the Incompressible Navier-Stokes Equations Using Consistent Mass and a Pressure Poisson Equation," Lawrence Livermore National Laboratory, UCRL-99406; in the *Proceedings of the ASME 1988 Symposium on Recent Developments in Computational Fluid Dynamics*, AMD-Vol. **95**, 57–73, Chicago, IL, November 28–December 2, 1988.

Grotch, S. L. (1989), "A Statistical Intercomparison of Temperature and Precipitation Predicted by Four General Circulation Models with Historical Data," Lawrence Livermore National Laboratory, UCRL-101726.

Grotch, S. L. (1989), "An Intercomparison of General Circulation Model Predictions of Regional Climate Change," Lawrence Livermore National Laboratory, UCRL-102793.

Grotch, S. L. (1989), "The Distribution of the Correlation between Large Scale Averages and Component Members," in the *Proceedings of the Fourteenth Annual Climate Diagnostics Workshop,* Scripps Institution of Oceanography, La Jolla, CA, October 16–20, 1989.

Gudiksen, P. H. (1989), "A Case Study of the Hazards Associated with Accidental Releases of Liquid Chlorine," Lawrence Livermore National Laboratory, UCRL-102258.

Gudiksen, P. H., R. Lange, L. L. Edwards, and T. F. Harvey (1989), "Atmospheric Dispersion Modeling in Support of Emergency Response," Lawrence Livermore National Laboratory, UCRL-102259.

Hudson,* J. G. (1989), "An Instantaneous CCN Spectrometer," Lawrence Livermore National Laboratory, UCRL-21154, LLNL Subcontract No. 6311805, Desert Research Institute.

Hudson,* J. G., C. F. Rogers,* and J. Hallett* (1989), "Water Nucleation Properties of Chaparral Fire Aerosol Particles," Lawrence Livermore National Laboratory, UCRL-21153, LLNL Subcontract No. 6311805, Desert Research Institute.

Kinnison,** D. E., and D. J. Wuebbles (1989), "Preventing Depletion of Stratospheric Ozone—Implications on Future Aircraft Emissions," Lawrence Livermore National Laboratory, UCRL-99926, Rev. 1; Air and Waste Management Association paper 89-4.7.

Knox, J. B. (1989), "Backgrounder Contribution #18: Climate Scenarios Selected for the First UC/DOE Workshop," Lawrence Livermore National Laboratory, UCID-21634.

Knox, J. B. (1989), "Introduction to Background Materials for Workshop #1: Global Climate Change and Its Effects on California," Lawrence Livermore National Laboratory, UCID-21631.

Knox, J. B., D. L. Ermak, R. Lange, and D. J. Rodriguez (1988), "Selecting Model Performance Measures for Air Quality Model Validations," Lawrence Livermore National Laboratory, UCRL-98038, Extended Abstract.

Koopman, R. P. (1989), "Cooperative, Multi-Disciplinary Problem Solving for Chemical Accidents," Lawrence Livermore National Laboratory, UCRL-101850.

Koopman, R. P., D. L. Ermak, and S. T. Chan (1988), "A Review of Recent Work in Atmospheric Dispersion of Large Spills," Lawrence Livermore National Laboratory, UCRL-97377.

Koopman, R. P., and K. W. Schatz† (1989), "Effectiveness of Water Spray Mitigation System for Accidental Releases of Hydrogen Fluoride," Lawrence Livermore National Laboratory, UCRL-21214, vols. I–VI and Summary, Industry Cooperative HF Mitigation/Assessment Program—Water Spray Subcommittee.

Lange, R., T. J. Sullivan, and P. H. Gudiksen (1989), "Simulation of Atmospheric Dispersion of Radioactivity from the Chernobyl Accident," Lawrence Livermore National Laboratory, UCRL-101507.

Lee, R. L., and N. K. Madsen (1989), "A Mixed Finite Element Formulation for Maxwell's Equations in the Time Domain," Lawrence Livermore National Laboratory, UCRL-99536, Rev. 1.

Lee, R. L., and N. K. Madsen (1988), "A Staggered-Grid Finite Element Solution Technique for the Maxwell's Equations in the Time Domain," Lawrence Livermore National Laboratory, UCRL-98822.

MacCracken, M. C. (1988), "Greenhouse Warming: What Do We Know?" Lawrence Livermore National Laboratory, UCRL-99998; in the *Proceedings of the Conference on the Implications of Climatic Change for California,* Pacific Institute, Berkeley, CA, Nov. 21, 1988.

MacCracken, M. C. (1988), "Scenarios for Future Climate Change: Results of GCM Simulations," Lawrence Livermore National Laboratory, UCRL-100144; in the *Proceedings of the First United States-Canada Symposium on the Impact of Climate on the Great Lakes Basin,* Illinois State Water Survey, Chicago, IL, September 27–29.

MacCracken, M. C. (1989), "Climate Projections with Regional Resolution," Lawrence Livermore National Laboratory, UCRL-100721, Rev. 1.

MacCracken, M. C. (1989), "Greenhouse Gases: Changing the Global Climate," Lawrence Livermore National Laboratory, UCRL-101837; in the *Proceedings of the International Seminars on Nuclear War: 9th Session,* Ettore Majorana Centre for Scientific Culture, Erice, Sicily, Italy, August 19–24, 1989.

MacCracken, M. C., et al. (1989), "Climate Caucus Report: Opportunities for Bridging the Gaps from Effects to Impacts," Lawrence Livermore National Laboratory, UCRL-101735; Summary of U. C. Davis Workshop on Global Climate Change and Its Effects on California, Davis, CA, July 10–12, 1989.

MacCracken, M. C., et al. (1989), "DOE Carbon Dioxide Research Program Workshop—Quantifying the Links between Change in Radiative Balance and Atmospheric Temperature," Lawrence Livermore National Laboratory, UCRL-101736; Summary of the DOE Carbon Dioxide Research Program Workshop, Germantown, MD, April 24–25, 1989.

Mitchell, C. S. (1988), "Graphical Display of Dispersion Model Results by the ARAC Site System," Lawrence Livermore National Laboratory, UCRL-97910; in the *Proceedings, American Nuclear Society Topical Meeting on Emergency Response—Planning, Technologies, and Implementation,* Charleston, SC, September 26–28, 1988.

Ng, Y. C., H. C. Rodean, and L. R. Anspaugh (1988), "Incorporation of Additional Radionuclides and the External Pathway into the BECAMP Radiological Assessment Model," Lawrence Livermore National Laboratory, UCRL-53893.

O'Connor, C. C., and C. C. Covey (1988), "Data Structure and Memory Management in the NCAR/LLNL Community Climate Model (CCM1L)," Lawrence Livermore National Laboratory, UCID-21601.

Ohmstede, W. D., R. T. Cederwall, and R. E. Meyers (1989), "Investigation of Rossby-Number Similarity in the Neutral Boundary Layer Using Large-Eddy Simulation," Lawrence Livermore National Laboratory, UCRL-97853; in the *Proceedings, 8th American Meteorological Society Symposium on Turbulence and Diffusion,* San Diego, CA, April 26–29, 1988.

Patrinos,[†] A., J. B. Knox, and T. J. Sullivan (1989), "Atmospheric Science and Emergency Preparedness: ARAC as an Example of the U.S. DOE/OHER Perspective," in the *Proceedings of the 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation*, Luxembourg, May 16–19, 1989.

Penner, J. E. (1989), "Cloud Albedo, Greenhouse Effects, Atmospheric Chemistry, and Climate Change," Lawrence Livermore National Laboratory, UCRL-99928; in the *Proceedings of the 82nd APCA Annual Meeting and Exhibition*, Anaheim, CA, June 25–30, 1989.

Penner, J. E., and P. S. Connell (1988), "Pollutant Transport Study: Bay Area to North Central Coast Air Basin," Lawrence Livermore National Laboratory, UCID-21287, Rev. 1.

Penner, J. E., P. S. Connell, D. J. Wuebbles, and C. C. Covey (1988), "Climate Change and Its Interactions with Air Chemistry: Perspectives and Research Needs," Lawrence Livermore National Laboratory, UCRL-21111 Executive Summary.

Penner, J. E., and R. P. Koopman (1988), "Impact of NO_x Emissions on Atmospheric Chemistry and Dense and Toxic Gas Modelling," *Energy and Technology Review*, Lawrence Livermore National Laboratory, UCRL-52000-89-7/8, pg. 72.

Rodean, H. C. (1989), "Modeling the Release and Dispersion of Hazardous Materials with Complex Behavior," Lawrence Livermore National Laboratory, UCRL-100029.

Rodean, H. C. (1989), "Modeling the Release and Dispersion of Hazardous Materials with Complex Behavior," Lawrence Livermore National Laboratory, UCRL-100029; presented at the 1989 JANNAF Safety and Environmental Protection Subcommittee Meeting, San Antonio, TX, April 3–7, 1989.

Rodean, H. C. (1989), "Toward More Realistic Material Models for Release and Dispersion of Heavy Gases," Lawrence Livermore National Laboratory, UCRL-53904.

Rodriguez, D. J. (1988), "Long-Range Transport: Evaluation of a Particle-in-Cell Model Using Sources in the U.S. and U.S.S.R.," Lawrence Livermore National Laboratory, UCRL-99305; in the *Proceedings 17th NATO/CCMS International Technical Meeting on Pollution Modelling and Its Application*, Cambridge, England, September 19–22, 1988.

Rosen, L. C., J. R. Creighton, M. A. Mansigh, and J. Ipser* (1989), "Laser Interactions with Aerosol Aureoles," Lawrence Livermore National Laboratory, UCID-21539.

Rosen, L. C., and J. Ipser* (1989), "Scattering of Ground Based Lasers by Atmospheric Aerosol Aureoles," Lawrence Livermore National Laboratory, UCRL-99232; in the *Proceedings of the SPIE Symposium on Lasers and Optics*, Vol. 1060, Los Angeles, CA, January 15–20, 1989.

Schalk,* W. W., III, and K. T. Foster (1989), "Dose Assessment during Complex Meteorology in the Texas Panhandle," Lawrence Livermore National Laboratory, UCRL-101216.

Schatz,[†] K. W., and R. P. Koopman (1989), "Water Spray Mitigation of Hydrofluoric Acid Releases," Lawrence Livermore National Laboratory, UCRL-101995.

Schlesinger,* M. E., and T. P. Barnett* (1989), "On Greenhouse Gas Signal Detection Strategies," Lawrence Livermore National Laboratory, UCRL-21147; prepared for subcontract #B100987 by Ocean Research Consultants.

Shinn, J. H., R. T. Cederwall, A. C. Stoker, and M. G. Novo (1988), "Environmental Assessment: Re-entry Vehicle Impact Dispersing Beryllium and Depleted Uranium, Illeginni Island, Marshall Islands District," Lawrence Livermore National Laboratory, UCID-21424.

Shinn, J. H., R. T. Cederwall, K. C. Lamson, and C. S. Mitchell (1989), "Beryllium Dispersion Near Explosive Firing Tables: A Comparison of Computed and Observed Results," Lawrence Livermore National Laboratory, UCID-21682.

Shinn, J. H., L. A. Sharmer,* R. T. Cederwall, M. G. Novo,* and C. S. Mitchell (1988), "Report on Environmental Effects at Yuma Proving Ground from Continued Testing of Projectiles Containing Beryllium and Depleted Uranium," Lawrence Livermore National Laboratory, UCID-21277.

Sullivan, T. J., (1989), "ARAC: A Computer-Based Emergency Dose-Assessment Service," Lawrence Livermore National Laboratory, UCRL-99984; in the *Proceedings of the 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation,* Luxembourg, May 16–19, 1989.

Sullivan, T. J. (1989), "Real-Time Global Mutual Aid for Atmospheric Releases of Radioactivity is Possible Today," Lawrence Livermore National Laboratory, UCRL-101718.

Sullivan, T. J., J. S. Nasstrom, G. D. Greenly (1989), "ARAC: Early Phase Dose Assessment for the DOE FRMAP," Lawrence Livermore National Laboratory, UCRL-101355, Rev. 1.

Taylor, K. E. (1989), "Briefing of the California Senate Special Committee on Solid and Hazardous Waste 'CO_2 and the Greenhouse Effect'," Lawrence Livermore National Laboratory, UCID-21625.

Walker, H. (1989), "Use of the 1:2,000,000 Digital Line Graph Data in Emergency Response," Lawrence Livermore National Laboratory, UCRL-99435.

Walker, H., R. P. Freis, D. N. Williams, and C. D. Wimple (1989), "The Use of GKS and CGM for the Display of Graphics Products," Lawrence Livermore National Laboratory, UCRL-99285.

Walker, H., and G. L. Hage (1989), "A Geographical Basis for Long-Range Dose Assessment Calculations," Lawrence Livermore National Laboratory, UCRL-101353.

Wuebbles, D. J. (1989), "Beyond CO_2—The Other Greenhouse Gases," Lawrence Livermore National Laboratory, UCRL-99883; Air and Waste Management Association paper 89-119.4.

Wuebbles, D. J., and J. E. Penner (1988), "Sensitivity of Urban/Regional Chemistry to Climate Change: Report of the Workshop," Lawrence Livermore National Laboratory, UCRL-99436.

Abstracts and Presentations

Atherton, C. S., J. E. Penner, J. J. Walton, J. E. Dignon,** and S. Hameed,* (1989), "Deposition and the Global Reactive Nitrogen Cycle," AGU Fall Meeting, December 4–8, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101977 Abstract.

Atherton, C. S., J. E. Penner, J. J. Walton, and S. Hameed* (1989), "The Global Cycle of Reactive Nitrogen," IAMAP '89 Conference, August 7–11, 1989, Whiteknights, Reading, United Kingdom; also Lawrence Livermore National Laboratory, UCRL-100209.

Baskett, R. L., and C. S. Mitchell (1989), "Evaluation of an Emergency Response Model with Instantaneous Air Concentrations during Stable Conditions," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101215.

Bradley, M. M. (1988), "Nucleation Scavenging: Simulations with a Three-Dimensional Cloud Model Using a New CCN Activation Parameterization," presented at the World Meteorological Organization Second International Cloud Modeling Workshop, August 8–12, 1988, Toulouse, France; also Lawrence Livermore National Laboratory, UCRL-97421 Abstract.

Bradley, M. M. (1988), "Recent Advances in the Three-Dimensional Numerical Simulation of Nucleation Scavenging within Pyrogenic Clouds," presented at the Global Effects Programs Technical Meeting, Defense Nuclear Agency, April 19–21, 1988, Santa Barbara, CA; also Lawrence Livermore National Laboratory, UCRL-98574 Abstract.

Bradley, M. M., J. E. Penner, and L. L. Edwards (1989), "A Numerical Modeling Study of the Hardiman Township, Ontario Prescribed Burn," American Association for Aerosol Research, October 10–13, 1989, Reno, NV; also Lawrence Livermore National Laboratory, UCRL-100453 Abstract.

Chan, S. T., J. M. Leone, and R. L. Lee (1988), "A Hydrostatic Mesoscale Model Using Finite Element and Finite Difference Techniques," 7th International Conference on Finite Element Methods in Flow Problems, April 3–8, 1989, Huntsville, AL; also Lawrence Livermore National Laboratory, UCRL-97615.

Chan, S. T., H. C. Rodean, R. T. Cederwall, and R. E. Meyers† (1989), "Numerical Simulation of Dense-Gas Dispersion in the Shoreline Environment," JANNAF Safety and Environmental Protection Subcommittee Meeting, April 3–7, 1989, San Antonio, TX; also Lawrence Livermore National Laboratory, UCRL-100030.

Chen,* H. Y., M. F. Iskander,* and J. E. Penner (1989), "Electromagnetic Properties of Fractal Aerosol Agglomerates," presented at the 1989 IEEE Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting, June 26–30, 1989, San Jose, CA.

Connell, P. S., and D. J. Wuebbles (1989), "Chlorofluorocarbon Alternatives and Stratospheric Ozone: Ozone Depletion Potentials Defined with a Two-Dimensional Model," AGU Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101745.

Connell, P. S., and D. J. Wuebbles (1989), "Evaluating CFC Alternatives from the Atmospheric Viewpoint," 82nd APCA Annual Meeting and Exhibition, June 25–30, 1989, Anaheim, CA; also Lawrence Livermore National Laboratory, UCRL-99927, Rev. 1.

Covey, C., S. J. Ghan, J. J. Walton, and P. R. Weissman† (1989), "Global Environmental Effects of Impact-Generated Aerosols: Results from a General Circulation Model," Geological Society of America Special Paper No. 247 (in press); also Lawrence Livermore National Laboratory, UCRL-98894.

Covey, C., and S. L. Thompson,† (1989), "Testing the Effects of Ocean Heat Transport on Climate," AGU 1989 Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-100558.

Dickerson, M. H., and D. L. Ermak (1988), "The Evaluation of Emergency Response Trace Gas and Dense-Gas Dispersion Models," American Meteorological Society, sponsored by the Advanced Studies Institute Short Course on the Meteorological Aspects of Emergency Response, September 28–29, Charleston, SC; also Lawrence Livermore National Laboratory, UCRL-99348.

Dickerson, M. H., and K. T. Foster (1989), "Utilization of Dose Assessment Models to Facilitate Off-Site Recovery Operations for Accidents at Nuclear Facilities," International Symposium on Recovery Operations in the Event of a Nuclear Accident or Radiological Emergency, November 6–10, 1989, Vienna, Austria; also Lawrence Livermore National Laboratory, UCRL-101842.

Dickerson, M. H., and T. J. Sullivan (1988), "The Atmospheric Release Advisory Capability (ARAC): A Federal Emergency Response Capability," 81st Annual APCA Meeting, June 20–24, 1988, Dallas, TX; also Lawrence Livermore National Laboratory, UCRL-98435.

Dignon,** J., J. E. Penner, J. Walton, S. Hameed,* and S. Ghan (1989), "Global Simulation of ^{222}Rn and ^{210}Pb in a Three-Dimensional Lagrangian Trace Model," American Geophysical Union, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-102196.

Edwards, L. L., T. F. Harvey, and S. E. Pitovranov[†] (1989), "Real-Time Regression Schemes for Integrating Measurements with Emergency Response Predictions," Second International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, May 16–19, 1989, Luxembourg; also Lawrence Livermore National Laboratory, UCRL-99969, Rev. 1.

Edwards, L. L., and J. E. Penner (1988), "A Parametric Study of Condensation Growth and Nucleation Scavenging over Large Fires," Lawrence Livermore National Laboratory, UCRL-97422.

Ellsaesser, H. W. (1988), "A Different View of the Climatic Effect of CO_2," Annual Meeting of the California Cooperative Snow Survey Program, Granlibakken Resort, December 8, 1988, Tahoe City, CA.

Ellsaesser, H. W. (1989), "The Benefits of Increased CO_2 Have Been Ignored and the Warming Exaggerated," Seminar in U.S. Geological Survey Global Change Seminar Series, USGS Auditorium, December 8, 1989, Reston, VA.

Ellsaesser, H. W. (1989), "The Benefits of Increased CO_2 Have Been Ignored and the Warming Exaggerated," presented by invitation at Panel Discussion on Global Climate Change, 1989 Pacific Environmental Conference, Mansfield Center for Pacific Affairs, Montana State University, October 22–25, 1989, Bozeman, MT.

Ellsaesser, H. W., et al. (1989), "Global Warming: Real or Imaginary?" Debate during Education Week on Global Warming, November 5–12, 1989, Bradley University, Peoria, IL.

Erickson,** D. J., III, S. J. Ghan, and J. E. Penner (1989), "Three-Dimensional Modeling of the Global Atmospheric Sulfur Cycle: A First Step," American Association for Aerosol Research Annual Meeting, October 9–13, 1989, Reno, NV.

Erickson,** D. J., III, J. J. Walton, S. J. Ghan, and J. E. Penner (1989), "3-D Modeling of the Global Atmospheric Sulfur Cycle: The Origin of Cloud Condensation Nuclei Over the North Atlantic Region," 1989 AGU Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101980.

Ermak, D. L. (1988), "SLAB: A Denser-Than-Air Atmospheric Dispersion Model," EPA Workshop on Toxic Air Contamination Modeling, October 17–21, 1988, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-99822.

Ermak, D. L. (1989), "A Description of the SLAB Model," JANNAF Safety & Environmental Protection Subcommittee Meeting, April 3–6, 1989, San Antonio, TX; also Lawrence Livermore National Laboratory, UCRL-100028.

Gates, W. L. (1989), "The Physical Basis for the Study of the Climate System and its Fluctuations," International Conference and Workshop on Climatic Fluctuations and Their Socio-Economic Impact, November 13–17, 1989, Toulouse, France; also Lawrence Livermore National Laboratory, UCRL-101832.

Gates, W. L. (1989), "The Quest for Reliable Regional Scenarios of Climate Change," Conference on Global Climate Change and its Effects on California, U.C. Davis, June 6–9, 1989.

Gates, W. L., and G. L. Potter (1989), "Simulation of the Climatic Effects of Increased CO_2 with a Coupled Atmosphere/Upper Ocean Model," International Conference on Modelling of Global Climate Change and Variability, Hamburg, Federal Republic of Germany, September 11–15, 1989.

Ghan, S. J. (1989), "Chronic Climatic Effects of Nuclear War," Annual American Association for Aerosol Research Meeting, October 10–13, 1989, Reno, NV; also Lawrence Livermore National Laboratory, UCRL-100345 Abstract.

Ghan, S. J., K. E. Taylor, J. E. Penner, and D. J. Erickson** (1989), "Marine CCN Concentration and Cloud Distributions," Annual American Association for Aerosol Research Meeting, October 10–13, 1989, Reno, NV; also Lawrence Livermore National Laboratory, UCRL-100346 Abstract.

Grant, K. E., R. G. Ellingson,* and D. J. Wuebbles (1989), "Sensitivity of a Two-Dimensional Chemistry-Transport Model to Changes in Parameterization of Radiative Processes," International Radiation Symposium, August 18–24, 1988, Lilli, France; also Lawrence Livermore National Laboratory, UCRL-98443, Rev. 1.

Gresho, P. M. (1989), "New Insights Regarding Projection Methods for Time-Dependent Viscous Incompressible Flows," University of Minnesota Supercomputer Institute, Minneapolis.

Gresho, P. M. (1989), "On Intermediate Boundary Conditions for the Time-Dependent Incompressible Navier-Stokes Equations via Projection Methods," Eighth GAMM Conference on Numerical Methods in Fluid Mechanics, Delft, The Netherlands; also Lawrence Livermore National Laboratory, UCRL-100479.

Gresho, P. M., and S. T. Chan (1988), "Semi-Consistent Mass Techniques for Solving the Incompressible Navier-Stokes Equations," an invited lecture for the 1st International Conference on Computational Methods in Flow Analysis, September 5–8, 1988, Okayama, Japan; also Lawrence Livermore National Laboratory, UCRL-99503.

Gresho, P. M., J. M. Leone, Jr., G. Evans,† and S. Paolucci† (1989), "Outflow Boundary Conditions for Incompressible Flows: Finite Difference Method vis-a-vis Finite Element Method," Seventh International Conference on FEM in Flow Problems, University of Alabama, April 3–7, 1989, Huntsville, AL; also Lawrence Livermore National Laboratory, UCRL-99899 Abstract.

Grotch, S. L. (1989), "An Intercomparison of General Circulation Model Predictions of Regional Climate Change," presented at the International Conference on Modelling of Global Climate Change and Variability, Hamburg, Federal Republic of Germany, September 11–15, 1989; also Lawrence Livermore National Laboratory, UCRL-102793.

Grotch, S. L. (1989), "Statistical Intercomparison of Temperature and Precipitation Predicted by Four General Circulation Models with Historical Data," Workshop on Greenhouse-Gas-Induced Climate Change: A Critical Appraisal of Simulations and Observations, May 8–12, 1989, Amherst, MA, August; also Lawrence Livermore National Laboratory, UCRL-101726.

Gudiksen, P. H. (1989), "A Case Study of the Hazards Associated with Accidental Releases of Liquid Chlorine," Workshop on Air Pollution Abatement Strategies sponsored by Rajasthan Pollution Control Board, December 17–18, 1989, Jaipur, India; also Lawrence Livermore National Laboratory, UCRL-102258.

Gudiksen, P. H., R. T. Cederwall, and D. J. Rodriguez (1989), "ANATEX Data Quality and Use in LLNL Model Evaluation," Meteorology Working Group Meeting, Air Force Technical Applications Center, June 28–29, 1989, Patrick AFB, FL.

Gudiksen, P. H., W. E. Clements, R. P. Hosker, Jr., C. D. Whiteman, W. D. Neff, R. L. Coulter, and G. E. Start, (1989), "Field Studies for Determining the Characteristics and Dynamics of Local Circulations," 2nd International Workshop on Real-Time Computing, May 15–19, 1989, Luxembourg; also Lawrence Livermore National Laboratory, UCRL-100924.

Gudiksen, P. H., R. Lange, L. L. Edwards, and T. F. Harvey (1989), "Atmospheric Dispersion Modeling in Support of Emergency Response," Workshop on Environmental Risk Analysis, Indian Ministry of Environment, December 12–15, 1989, New Delhi, India; also Lawrence Livermore National Laboratory, UCRL-102259.

Holve,* D. J., T. L. Harvill,* K. W. Schatz,[†] and R. P. Koopman (1989), "In-Situ Optical Measurements of Hydrofluoric Acid Aerosols," AIChE Meeting on Controls of Accidental Releases of Hazardous Gases, August 1989, Philadelphia, PA; also Lawrence Livermore National Laboratory, UCRL-101996.

Iskander,* M. F., H. Y. Chen,* and J. E. Penner (1989), "Calculation of Optical Properties of Impure Cloud Drops Using Realistic Modeling of Scavenging of Carbonaceous Particles," AAAR meeting in the Symposium on the Global Climatic Effects of Aerosols, October 10–13, 1989, Reno, NV.

Iskander,* M. F., H. Y. Chen,* and J. E. Penner (1989), "Light Scattering and Absorption by Fractal Agglomerates of Smoke Aerosols," 1989 SBMO International Microwave Symposium, July 24–27, 1989, Sao Paulo, Brazil.

Kinnison,** D. E., and D. J. Wuebbles (1989), "Preventing Depletion of Stratospheric Ozone—Implications on Future Aircraft Emissions," 82nd APCA Annual Meeting and Exhibition, June 25–30, 1989, Anaheim, CA; also Lawrence Livermore National Laboratory, UCRL-99926, Rev. 1.

Kinnison,** D. E., and D. J. Wuebbles (1989), "Two-Dimensional Model Study of Nuclear Tracer Transport in the Stratosphere," AGU Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101831.

Knox, J. B., D. L. Ermak, R. Lange, and D. J. Rodriguez (1988), "Selecting Model Performance Measures for Air Quality Model Validations," presented at the American Nuclear Society meeting on Emergency Response: Planning, Technologies, and Implementation, September 1988, Charleston, SC; also Lawrence Livermore National Laboratory, UCRL-98038 Extended Abstract.

Koopman, R. P. (1989), "Cooperative, Multi-Disciplinary Problem Solving for Chemical Accidents," Conference on Technology-Based Confidence Building: Energy & Environment, July 9–14, 1989, Santa Fe, NM; also Lawrence Livermore National Laboratory, UCRL-101850.

Koopman, R. P., D. L. Ermak, and S. T. Chan (1988), "A Review of Recent Work in Atmospheric Dispersion of Large Spills," presented at the 1988 AIChE Hazardous Material Spills Conference, May 16–19, 1988, Chicago, IL; also Lawrence Livermore National Laboratory, UCRL-97377.

Kreidenweis,[†] S., J. E. Penner, F. Yin,[†] D. J. Erickson,** and J. H. Seinfeld,[†] "The Effects of Dimethylsulfide Fluxes upon Marine Aerosol Concentrations," AAAR Symposium on the Global Climatic Effects of Aerosols, October 10–13, 1989, Reno, NV.

Lange, R., T. J. Sullivan, and P. H. Gudiksen (1989), "Simulation of Atmospheric Dispersion of Radioactivity from the Chernobyl Accident," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101507.

Lee, R. L., and J. M. Leone, Jr. (1988), "Applications of a Three-Dimensional Finite Element Model to Mountain-Valley Flows," First International Conference on Computational Methods in Flow Analysis, September 1–8, 1988, Okayama, Japan; also Lawrence Livermore National Laboratory, UCRL-97389.

Lee, R. L., and J. M. Leone, Jr. (1989), "Do Hydrostatic Flows Exist within Regions of Complex Terrain?" 5th Conference on Mountain Meteorology, June 25–29, 1990, Boulder, CO; also Lawrence Livermore National Laboratory, UCRL-102073 Abstract.

Lee, R. L., and N. K. Madsen (1988), "A Staggered-Grid Finite Element Solution Technique for the Maxwell's Equations in the Time Domain," First Woodward Conference Wave Phenomena, Theoretical, Computational and Practical Aspects, June 2–3, 1988, San Jose, CA; also Lawrence Livermore National Laboratory, UCRL-98822.

Leone, J. M., Jr., S. T. Chan, and R. L. Lee (1989), "A Meso-beta Model for Use in Emergency Response," Scientific Programme Committee of IAMAP '89, August 2–4, 1989, Reading, United Kingdom; also Lawrence Livermore National Laboratory, UCRL-100559 Abstract.

MacCracken, M. C. (1988), "Greenhouse Warming: What Do We Know?" Conference on the Implications of Climatic Change for California, November 21, 1988, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-99998.

MacCracken, M. C. (1988), "Scenarios for Future Climate Change: Results of GCM Simulations," First United States-Canada Symposium on the Impacts of Climate Change on the Great Lakes Basin, September 27–29, Chicago, IL; also Lawrence Livermore National Laboratory, UCRL-100144.

MacCracken, M. C. (1988), "Testimony to Energy and Power Subcommittee of the House Energy and Commerce Committee," U.S. House of Representatives, July 7, 1988.

MacCracken, M. C. (1989), "Climate Projections with Regional Resolution," First Annual National Academy of Sciences Symposium on Frontiers of Science, March 2–4, 1989, Irvine, CA; also Lawrence Livermore National Laboratory, UCRL-100721.

MacCracken, M. C. (1989), "Global Change: What's To Be Expected," 40th AIBS/ESA Symposium on Ecological Consequences of Global Change, August 6–10, 1989, Ontario, Canada; also Lawrence Livermore National Laboratory, UCRL-101212 Abstract.

MacCracken, M. C. (1989), "Greenhouse Gases: Changing the Global Climate," International Seminars on Nuclear War: 9th Session, Ettore Majorana Centre for Scientific Culture, August 19–24, 1989, Erice, Sicily, Italy; also Lawrence Livermore National Laboratory, UCRL-101837 Abstract.

MacCracken, M. C. (1989), "Greenhouse Gases: Changing the Global Climate," Fourth International Conference of the Israel Society for Ecology and Environmental Quality Sciences, June 4–8, 1989, Jerusalem, Israel; also Lawrence Livermore National Laboratory, UCRL-100721, Rev. 1.

MacCracken, M. C. (1989), "Greenhouse Gases: Changing the Nature of Our Environment," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101217.

Mitchell, C. S. (1988), "Graphical Display of Dispersion Model Results by the ARAC Site System," American Nuclear Society Topical Meeting on Emergency Response—Planning, Technologies, and Implementation, September 26–28, 1988, Charleston, SC.; also Lawrence Livermore National Laboratory, UCRL-97910.

Mitchell, C. S., K. T. Foster, R. L. Baskett,* J. G. Welch, G. D. Greenly, T. J. Sullivan, and K. P. Ellis (1989), "ARAC Site System Training: Introduction," 1989 Training Resources and Data Exchange Conference, October 23–25, 1989, Baltimore, MD, PR#15780.

Molenkamp, C. R. (1988), "Numerical Simulation of Coastal Clouds when Solar Radiation is Blocked by Smoke," DNA Global Effects Program Technical Meeting, April 19–21, 1988, Santa Barbara, CA; also Lawrence Livermore National Laboratory, UCRL-97424 Abstract.

Molenkamp, C. R. *(1988), "Numerical Simulation of Coastal Flows when Solar Radiation is Blocked* by Smoke," *10th International Cloud Physics Conference, August 15–20, 1988, Bad Homberg,* Federal Republic of Germany; also Lawrence Livermore National Laboratory, UCRL-97424 Abstract.

Molenkamp, C. R., and M. M. Bradley (1989), "Numerical Simulation of the Scavenging of Smoke from Large Fires" American Association for Aerosol Research, October 10–13, 1989, Reno, NV; also Lawrence Livermore National Laboratory, UCRL-100455 Abstract Part I.

Novakov,[†] T., A. D. A Hansen,[†] W. H. Benner,[†] J. E. Penner, V. Carey,[†] and X. Xun[†] (1989), "Modeling and Laboratory Investigations of Cloud Scavenging Processes," AAAR Symposium on the Global Climatic Effects of Aerosols, October 10–13, 1989, Reno, NV.

Offermann,[†] D., M. Riese,[†] and D. Wuebbles (1989), "Stratospheric Dynamics and Trace Gas Distribution: A Case Study," IAGA 6th Scientific Assembly, July 24–August 4, 1989, Exeter, England; also Lawrence Livermore National Laboratory, UCRL-100716 Abstract.

Ohmstede, W. D., R. T. Cederwall, and R. E. Meyers[†] (1989), "Investigation of Rossby-Number Similarity in the Neutral Boundary Layer Using Large-Eddy Simulation," 8th American Meteorological Society Symposium on Turbulence and Diffusion, April 26–29, 1988, San Diego, CA; also Lawrence Livermore National Laboratory, UCRL-97853.

Penner, J. E. (1989), "Cloud Albedo, Greenhouse Effects, Atmospheric Chemistry, and Climate Change," 82nd APCA Annual Meeting and Exhibition, June 25–30, 1989, Anaheim, CA; also Lawrence Livermore National Laboratory, UCRL-99928.

Penner, J. E. (1989), "The Long-Range Transport of Carbonaceous Aerosols: A Perspective Based on Nuclear Winter Studies," European Aerosol Conference, September 18–23, 1989, Vienna, Austria; also Lawrence Livermore National Laboratory, UCRL-102197 Abstract.

Penner, J. E., C. S. Atherton, J. J. Walton, and S. Hameed* (1989), "The Global Cycle of Reactive Nitrogen," International Conference on Global and Regional Environmental Atmospheric Chemistry, May 3–10, 1989, Beijing, China; also Lawrence Livermore National Laboratory, UCRL-100209 Abstract.

Radke,[†] L. F., A. S. Ackerman,[†] J. H. Lyons,[†] D. A. Hegg,[†] P. V. Hobbs,[†] J. E. Penner, and R. E. Weiss[†](1989), "Effects of Long-Range Transport on the Smoke from a Forest Fire," IAMAP 1989 Symposium on Meteorological Aspects of Mesoscale and Long-Range Pollution Transport, July 31–August 12, 1989, University of Reading, United Kingdom; also Lawrence Livermore National Laboratory, UCRL-100438 Abstract.

Rodean, H. C. (1989), "Modeling the Release and Dispersion of Hazardous Materials with Complex Behavior," 1989 JANNAF Safety and Environmental Protection Subcommittee Meeting, April 3–7 1989, San Antonio, TX; also Lawrence Livermore National Laboratory, UCRL-100029.

Rodriguez, D. R. and R. T. Cederwall (1989), "Appraising the Performance of a Particle-in Cell Model Using the ANATEX Data," 6th AMS Joint Conference on Air Pollution Meteorology, January 29–February 3, 1989, Anaheim, CA.

Roger,* F., J. Hudson,* J. H. Hallett,* and J. E. Penner (1989), "Water Nucleation Activity of Coagulated Crude Oil and Mixed Crude Oil/Wood Smoke Particles: Theory and Experiment," AAAR Symposium on the Global Climatic Effects of Aerosols, October 10–13, 1989, Reno, NV.

Rosen, L. C., and J. Ipser* (1988), "Scattering of Laser Beams through Interactions with Aerosol Aureoles," Physics of Directed Energy Propagation in the Atmosphere, March 23–30, 1989, Los Cruces, NM; also Lawrence Livermore National Laboratory, UCRL-98157 Abstract.

Rosen, L. C., and J. Ipser* (1989), "Scattering of Ground Based Lasers by Aerosols in an Atmosphere with Enhanced Particle Content," American Association for Aerosol Research, October 10–13, 1989, Reno, NV; also Lawrence Livermore National Laboratory, UCRL-100442 Abstract.

Schalk,* W. W., III, and K. Foster (1989), "Dose Assessment during Complex Meteorology in the Texas Panhandle," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101216.

Schatz,† K. W., and R. P. Koopman (1989), "Water Spray Mitigation of Hydrofluoric Acid Releases," AIChE Meeting on "Controls of Accidental Releases of Hazardous Gases," August 1989, Philadelphia, PA; also Lawrence Livermore National Laboratory, UCRL-101995.

Sperber,** K. R. (1989), "The Southwest Indian Monsoon Response to Southern Oscillation Simulation in the OSU Coupled Upper Ocean/Atmosphere GCM," American Geophysical Union, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-102792 Abstract; *EOS* **70**, 1159.

Sperber,** K. R., S. Hameed,* W. L. Gates, and G. L. Potter (1989), "Southern Oscillation in the OSU Coupled Upper Ocean/Atmosphere GCM," Fourteenth Annual Climate Diagnostics Workshop, October 16–20, 1989, Scripps Institution of Oceanography, La Jolla, CA.

Sullivan, T. J. (1988), "ARAC: Evolution by Accident," ANS Topical Meeting, September 26–28, 1988, Charleston, SC; also Lawrence Livermore National Laboratory, UCRL-98033 Extended Abstract.

Sullivan, T. J., (1989), "ARAC: A Computer-Based Emergency Dose-Assessment Service," 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, May 16–19, 1989, Luxembourg; also Lawrence Livermore National Laboratory, UCRL-99984.

Sullivan, T. J. (1989), "Real-Time Global Mutual Aid for Atmospheric Releases of Radioactivity is Possible Today," Conference on Technology Based Confidence Building: Energy and Environment, July 9–14, 1989, St. John's College, Santa Fe, NM; also Lawrence Livermore National Laboratory, UCRL-101718.

Sullivan, T. J., J. S. Nasstrom, and G. D. Greenly (1989), "ARAC: Early Phase Dose Assessment for the DOE FRMAP," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101355, Rev. 1.

Taylor, K. E. (1988), "Time-Split Methods: Some Avoidable Pitfalls," NATO Advanced Study Institute on Modeling the Ocean General Circulation and Geochemical Tracer Transport, February 15–26, 1988, Les Houches, France; also Lawrence Livermore National Laboratory, UCRL-98451 Abstract.

Taylor, K. E., C. C. Covey, and R. E. Dickinson† (1989), "Upper Limit for the Sea Ice Albedo Feedback Contribution to Global Warming," AGU 1989 Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101744.

Taylor, K. E., and S. J. Ghan (1989), "Cloud Liquid Water Feedback and Global Climate Sensitivity," International Conference on Modelling of Global Climate Change and Variability, September 11–15, 1989, Hamburg, Federal Republic of Germany; also Lawrence Livermore National Laboratory, UCRL-100309 Abstract.

Taylor, K. E., and S. J. Ghan (1989), "Changes in Cloud Distribution and Cloud Optical Properties in Global Sensitivity Experiments," International Liege Colloquium on Ocean Hydrodynamics: "Coupled Ocean-Atmosphere Models," May 8–12, 1989, Liege, Belgium; also Lawrence Livermore National Laboratory, UCRL-99960 Abstract.

Taylor, K. E., and M. C. MacCracken (1988), "Projected Effects of Increasing CO_2 and Trace Gases on Climate," American Society of Agronomy Symposium on the Impact of CO_2, Trace Gases, and Climate Change on Global Agriculture, November 27–December 2, 1988, Anaheim, CA; also Lawrence Livermore National Laboratory, UCRL-100228 Abstract.

Walker, H. (1989), "Use of the 1:2,000,000 Digital Line Graph Data in Emergency Response," 1989 ASPRS/ACSM Auto-Carto 9, April 2–7, 1989, Baltimore, MD; also Lawrence Livermore National Laboratory, UCRL-99435.

Walker, H., R. P. Freis, D. N. Williams, and C. D. Wimple (1989), "The Use of GKS and CGM for the Display of Graphics Products," CUBE Symposium, November 1988, Albuquerque, NM; also Lawrence Livermore National Laboratory, UCRL-99285.

Walker, H., and G. L. Hage (1989), "A Geographical Basis for Long-Range Dose Assessment Calculations," American Nuclear Society's 1989 Winter Meeting, November 26–30, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101353.

Wuebbles, D. J. (1989), "Beyond CO_2—The Other Greenhouse Gases," Air and Waste Management Association's 1989 Annual Meeting, June 25–30, 1989, Anaheim, CA; also Lawrence Livermore National Laboratory, UCRL-99883.

Wuebbles, D. J., and P. S. Connell (1989), "Ozone Depletion Potentials and Greenhouse Warming Potentials for CFCs and Possible Replacement Compounds," AGU Fall Meeting, December 4–8, 1989, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101841.

Wuebbles, D. J., and D. E. Kinnison** (1989), "Recent Calculations of the Response of the Middle Atmosphere to Solar Ultraviolet Irradiance Variations," IAGA 6th Scientific Assembly in Exeter, July 24–August 4, 1989, United Kingdom; also Lawrence Livermore National Laboratory, UCRL-100979 Abstract.

Yamada,† T., J. Leone, Jr., K. S. Rao,† M. H. Dickerson, D. Bader,† and M. Williams† (1989), "Applications of Complex Terrain Meteorological Models to Emergency Response Management," 2nd International Workshop of Real-Time Computation of the Environmental Consequences of a Accidental Release to the Atmosphere from a Nuclear Installation, May 16–19, 1989, Luxembourg.

Abstracts and Presentations Submitted for Conferences in 1990

Baskett, R. L., J. S. Nasstrom, and R. Lange (1989), "Emergency Response Model Evaluation Using Diablo Canyon Nuclear Power Plant Tracer Experiments," 18th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, May 13–17, 1990, Vancouver, Canada.

Baskett, R. L., J. S. Nasstrom, and R. Lange (1989), "The Value of On-Site Sodars Versus Nearest Radiosonde Sounding in Regional Emergency Response Modeling," Air & Waste Management Association 83rd Annual Meeting & Exhibition, June 24–29, 1990, Pittsburgh, PA.

Bradley, M. M., C. Chuang,** L. L. Edwards, and J. E. Penner (1989), "A Numerical Simulation of the Atmospheric Dynamics and Aerosol-Cloud Interactions of the Hardiman Township, Ontario Prescribed Burn," American Geophysical Union Chapman Conference on Global Biomass Burning: Atmospheric, Climate, and Biospheric Implications, March 19–23, 1990, Williamsburg, VA.

Bradley, M. M., and C. R. Molenkamp (1989), "Numerical Simulation of Aerosol Scavenging by Ice-Bearing Convective Clouds," Conference on Cloud Physics, July 23–27, 1990, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101997.

Bradley, M. M., K. R. Peterson, P. H. Gudiksen, and D. J. Rodriguez (1989), "Optical Depths over a Target Area Immediately Following a Massive Nuclear Strike: A Numerical Simulation," Cloud Impacts on DOD Operations and Systems 1989/90 Conference, Naval Postgraduate School, January 9–11, 1990, Monterey, CA; also Lawrence Livermore National Laboratory, UCRL-102432.

Chuang,** C. C., J. E. Penner, L. L. Edwards, and M. M. Bradley (1989), "The Effects of Entrainment on Nucleation Scavenging," *Conference on Cloud Physics, Preprints,* American Meteorological Society, July 23–27, 1990, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101990.

Dignon,** J. J., J. E. Penner, S. Hameed,* C. S. Atherton, and J. J. Walton (1989), "Biomass Burning and its Contribution to Nitrate Deposition in the Tropics," Chapman Conference on Biomass Burning, March 19–23, 1990, Williamsburg, VA; also Lawrence Livermore National Laboratory, UCRL-102195 and UCRL-102196 Abstract, Rev. 1.

Lange, R. (1989), "A Comparison of the Monte Carlo and the Flux Gradient Method for Atmospheric Diffusion," 18th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, May 13–17, 1990, Vancouver, Canada; also Lawrence Livermore National Laboratory, UCRL-102141.

Lee, R. L., and J. A. Ross (1989), "Finite Element Calculations of Flow and Dispersion Around Structures Using a Two-Equation Turbulence Model," 18th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, May 13–17, 1990, Vancouver, Canada; also Lawrence Livermore National Laboratory, UCRL-101981.

Leone, J. M., Jr., and P. H. Gudiksen (1989), "Nocturnal Flow on a Western Colorado Slope," 18th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, May 13–17, 1990, Vancouver, Canada; also Lawrence Livermore National Laboratory, UCRL-101986 Abstract.

Molenkamp, C. R. (1989), "Mesoscale Simulation of Coastal Clouds and Precipitation when the Incident Solar Radiation is Blocked by Smoke," 4th Conference on Mesoscale Processes, June 25–29, 1990, Boulder, CO; also Lawrence Livermore National Laboratory, UCRL-102266 Abstract.

Molenkamp, C. R., and M. M. Bradley (1989), "Parameterization of Aerosol Scavenging in a Convective Cloud Model," Conference on Cloud Physics, July 23–27, 1990, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101998.

Penner, J. E., S. J. Ghan, and J. J. Walton (1989), "The Role of Biomass Burning in the Global Budget and Cycle of Elemental Carbon," Chapman Conference on Global Biomass Burning, Atmospheric, Climate, and Biospheric Implications, March 19–23, 1990, Williamsburg, Virginia; also Lawrence Livermore National Laboratory, UCRL-101979 Abstract.

Rodriguez, D. J., and R. T. Cederwall (1989), Evaluating the Adequacy of Three Wind Field Products for Describing the Long Range Transport of Pollutants," 18th NATO/CCMS ITM on Air Pollution Modelling and its Application, May 13–17, 1990, Vancouver, Canada; also Lawrence Livermore National Laboratory, UCRL-102131 Abstract.

Rosen, L. C., K. E. Grant, and D. J. Wuebbles (1989), "The Computation of Biologically Effective Ultraviolet Radiation as a Result of Atmospheric Scenarios Including Trace Gases," Seventh Conference on Atmospheric Radiation, July 23–27, 1990, San Francisco, CA; also Lawrence Livermore National Laboratory, UCRL-101988 Abstract.

Wuebbles, D. J. (1989), "Interactions of Atmospheric Chemistry and Climate Change," American Chemical Society Meeting, January 1990, Berkeley, CA; also Lawrence Livermore National Laboratory, UCRL-102416.

Wuebbles, D. J., P. S. Connell, and D. E. Kinnison** (1989), "Global Atmospheric Modeling of Present and Future Ozone," 10th International Clean Air Conference, March 29, 1990, Auckland, New Zealand; also Lawrence Livermore National Laboratory, UCRL-101740.

Zhong,† S., J. M. Leone, Jr., and E. S. Takle† (1989), "A Three-Dimensional Numerical Simulation of Mesoscale Flow over KSC/CC Area of Florida," 4th Conference on Mesoscale Processes, June 25–29, 1990, Boulder, CO; also Lawrence Livermore National Laboratory, UCRL-102260 Abstract.

Miscellaneous Publications

Covey, C. C. (1988), "Review of 'Abrupt Climatic Change: Evidence and Implications,' W. H. Berger and L. D. Labeyrie (Eds.)," *Bulletin of the American Meteorological Society,* **69**, 1069–1070.

Covey, C. C. (1989), "Reply to comments on 'Atmospheric and Oceanic Heat Transport: Simulations Versus Observations'," *Climatic Change,* **15**, 481.

Covey, C. C. (1989), "Review of 'Climate Shocks: Natural and Anthropogenic' by K.Ya. Kondratyev," *Climatic Change,* **14**, 103–104.

Covey, C. C., K. E. Taylor, and J. S. Ellis (1988), "Review of 'The Geophysics of Sea Ice,' N. Untersteiner (Ed.)," *Climatic Change,* **11**, 209–211.

Edwards, L. L., and T. F. Harvey (1988), "Hybrid Particle Version of ADPIC Phase I," Lawrence Livermore National Laboratory, UASG-88-9, Rev. 1.‡

Ellsaesser, H. W. (1988), "A Different View of the Climatic Effect of CO_2 (the Greenhouse Effect)," presented in The Survey Research Center series, *Risk: Controversies on Social and Technological Dangers,* 119 Moses Hall, University of California, Berkeley, CA.

Ellsaesser, H. W. (1988), "The Greenhouse Effect: Science Fiction?" *Consumer's Research,* **71**, 27–31.

Ellsaesser, H. W. (1989), "A Scientist Looks at the 'Arrogance' of Environmentalists," *American Mining Congress Journal,* **75**, 22–23.

Ellsaesser, H. W. (1989), "Chernobyl: The Past and the Prognosis for the Future," by Yu. Izreal, published in PRAVDA, 4, March 20, 1989, (translation from Russian); also Lawrence Livermore National Laboratory, UCRL-Trans-12255.

‡ UASG reports are Unclassified Atmospheric Sciences Group substantive memoranda; those emphasizing technical and scientific topics are included here.

Ellsaesser, H. W. (1989), "Comment on 'Crisis in Politics of Climate Change Looms on Horizon' by Patrick J. Michaels," in the *Forum for Applied Research and Public Policy,* The University of Tennessee, Knoxville, TN (in press).

Ellsaesser, H. W. (1989), "Further Commentary on 'Global Effects of Meteorite Impacts and Volcanism' by Devendra Lal," in the *Global Climate Change: Human and Natural Influences,* S.F. Singer (Ed.), Paragon House, New York, NY, 373–375.

Ellsaesser, H. W. (1989), "Global 2000 Revisited: The Environmentalists' Errors," *EIR Science & Technology,* **16**, 22–29.

Ellsaesser, H. W. (1989), "President Bush's New Clean Air Bill: Lots of Money and Hot Air," *21st Century Science & Technology,* **2**, 19–23.

Ellsaesser, H. W. (1989), "Protect Us from the Environmentalists," *Newsday.*

Ellsaesser, H. W. (1989), "Review of 'Carbon Dioxide and Global Change: Earth in Transition' by Sherwood B. Idso," Lawrence Livermore National Laboratory, UCRL-102008; submitted to *Climate Change.*

Ellsaesser, H. W. (1989), "Scientific American on 'Managing Planet Earth', A Review," *21st Century Science & Technology,* **2**, 23–27.

Ellsaesser, H. W. (1989), "The Politicizing of Climate Science," *21st Century Science & Technology,* **2**, 7–8.

Ellsaesser, H. W. (1989), "The Politicizing of Science," *21st Century Magazine* (in press).

Ellsaesser, H. W. (1989), "The Rise of Environmentalism and the Downfall of Science," *The World & I* (in press).

Ellsaesser, H. W. (1989), "The Siren Song of Environmentalism," *The World & I,* **4**, 50–53.

Freis, R. P. (1989), "An Analytic Method for Solving the Radioactive Chain Decay Rate Equations," Lawrence Livermore National Laboratory, UASG-89-50.‡

Freis, R. P., T. F. Harvey, and L. L. Edwards (1989), "GENHAZ1, A Program to Calculate Time Dependent Toxicities," Lawrence Livermore National Laboratory, UASG-89-52.‡

Ghan, S. J. (1988), "Book review of 'Abrupt Climatic Change: Evidence and Implications,' by W. H. Berger and L. D. Labeyrie (Eds.)," for *Climatic Change,* **13**, 337-339.

Harvey, T. F. (1989), "Comments on Comparing our Estimates of Chernobyl Releases and Release Fractions with Soviet and Other Estimates," Lawrence Livermore National Laboratory, UASG-89-05.‡

Harvey, T. F., and L. L. Edwards (1988), "Challenge to a Claim that Chernobyl-4 Suffered a Second Criticality," Lawrence Livermore National Laboratory, UASG-88-2.‡

Harvey, T. F., and R. Lange (1988), "Long-Range Cloud-Passage Doses from Chernobyl-4 and a Hypothetical Tactical Nuclear War," Lawrence Livermore National Laboratory, UASG-88-6.‡

MacCracken, M. C. (1989), "Climate Change Activities in the Atmospheric and Geophysical Sciences Division," Lawrence Livermore National Laboratory, UASG-89-26.‡

MacCracken, M. C. (1989), "Comments on 'Rejuvenating the Ozone Layer' by L. Y. Sadler," *Chemical and Engineering News,* **Feb. 29**, p.2.

MacCracken, M. C. (1989), "On Empirical Projection of Future Temperature Increases," Lawrence Livermore National Laboratory, UASG-89-48.‡

Mitchell, C. S. (1989), "The ARAC Site System Training Video Tape Series," 1989 Training Resources and Data Exchange Conference, October 23–25, 1989, Baltimore, MD; also Lawrence Livermore National Laboratory, UASG-89-36.‡

Rodriguez, D. J., and J. M. Leone, Jr. (1989), "Development and Application of Numerical Models in Support of the RPP—Final Report, FY 1988," Lawrence Livermore National Laboratory, UASG-89-57.[‡]

Wuebbles, D. J. (with input from W. A. Matthew and H. Hitchman) (1988), "Perturbations to Ozone," Lawrence Livermore National Laboratory, CA, UASG-88-22.[‡]

Appendix F. Invited Seminar Speakers*

Leonid A. Bolshov, Institute of Nuclear Safety, U.S.S.R. Academy of Sciences, "U.S.S.R. Activities in Emergency Response," December 1, 1989.

Wallace Broecker, Lamont-Doherty Geological Observatory, "The Global Geochemistry of ^{210}Pb and ^{10}Be," July 20, 1989.

Garrett Campbell, Cooperative Institute for Research in the Atmosphere, Colorado State U., "Review of ISCCP and Results on the Time Evolution of Cloud Fields," November 14, 1988.

Robert Cess, Laboratory for Planetary Atmospheres Research, SUNY, Stony Brook, "Intercomparison and Interpretation of Satellite Derived Directional Albedos over Deserts," January 14, 1988.

Robert Cess, Laboratory for Planetary Atmospheres Research, SUNY, Stony Brook, "Inferring Surface Solar Absorption from Broad-Band Satellite Measurements: A Tutorial," June 28, 1988.

Robert Cess, Laboratory for Planetary Atmospheres Research, SUNY, Stony Brook, "Determining Clear-Sky Surface Solar Absorption from ERBE Data: Comparison with BAO Tower Measurements," August 23, 1989.

Robert Chervin, National Center for Atmospheric Research, Boulder, CO, and Albert Semtner, Naval Postgraduate School, Monterey, CA, "An Ocean Modeling System for Anticipated Super Computer Architecture and Ocean Problems of the 1990s—Today," January 28, 1988.

Robert Chervin, National Center for Atmospheric Research, "Recent Results from a Global Eddy-Resolving Ocean Circulation Model," December 18, 1989.

Hung-Neng Steve Chin, U. of Illinois, "Modeling of the Tropical Nonsquall and Squall Clusters and the Application to the Regional Impact of Global Climate Change," November 28, 1989.

Catherine Chuang, U. of Illinois, "A Numerical Model for the Axisymmetric Equilibrium Shape of Drops in Uniform Motion Effects of External Flow Electric Field and Surface Charge," March 22, 1989.

Geoff Clark, Australian Nuclear Science and Technology Organization, "Atmospheric Studies at the Australian Nuclear Science and Technology Organization," February 14, 1989.

Terry Clark, National Center for Atmospheric Research, Boulder, CO, "Overview of Some Topics in Small Scale Atmospheric Modeling," March 3, 1988.

Kelvin K. Droegemeier, School of Meteorology, U. of Oklahoma, Norman, OK, "Simulations of Thunderstorms and Microbursts: Applications to the Flight Safety Problem," June 17, 1988.

Robert Ellingson, Dept. of Meteorology, U. of Maryland, "A Technique for Estimating Outgoing Longwave Radiation from HIRS: Comparison with ERBE Data," June 23, 1988.

Scott Elliott, Dept. of Chemistry, U. of Calif., Irvine, "New Ligands in Sea Water: Hydrogen Sulfides," July 20, 1988.

David J. Erickson, III, Scripps Institution of Oceanography, La Jolla, CA, "Simulating Air-sea Gas Exchange," February 25, 1988.

Gary Geernaert, Naval Research Laboratory, Washington, D.C., "Studies of Wind Stress with Applications to Turbulent Exchange at the Air-Sea Interface," August 8, 1988.

Benjamin S. Giese, U. of Washington, "Aspects of the Equatorial Kelvin Wave Response to Episodic Forcing," February 28, 1989.

Filippo Giorgi, National Center for Atmospheric Research, "Simulation of Regional Climate Using a Limited-Area Model Nested in a General Circulation Model," December 5, 1989.

* Other than G-Division members

Steven D. Goldenberg, Atmospheric and Environmental Research, Inc., Cambridge, MA, "The Faint Young Sun Problem: The Role of Dynamic Feedback Mechanisms in a 2-D Climate Model," April 27, 1989.

Jake Hales, Battelle Pacific Northwest Laboratories, "An Overview of Atmospheric Chemistry Modeling at Pacific Northwest Laboratory," March 14, 1989.

Sultan Hameed, Dept. of Mechanical Engineering and Laboratory for Planetary Atmospheres Research, SUNY, Stony Brook, "Some Properties of the Atmosphere and Oceans as Simulated by the Oregon State General Circulation Model," August 18, 1988.

Neil Harris, U. of Calif., Irvine, "Trends in Stratospheric Ozone," September 5, 1989.

Harshvardhan, Dept. of Earth and Atmospheric Sciences, Purdue U., "Radiation, Clouds, and Climate," July 17, 1989.

Richard T. Hasbrouck, Electronics Engineering Dept., Lawrence Livermore National Laboratory, "LLNL Participation in NASA's Rocket-Triggered Lightning Program," May 17, 1988.

Thomas Hauf, Deutsche forschungs-und Versuchsanstalt Für Luftund Raumfahrt, "Three-Dimensional Numerical Experiments on Convectively Forced Internal Gravity Waves," April 17, 1989.

T. L. Keller, Palo Alto Scientific Center, IBM, "Energy and Momentum Transport by Gravity Waves," March 10, 1989.

Joseph B. Klemp, National Center for Atmospheric Research, Boulder, CO, "The Dynamics of Squall Lines," June 10, 1988.

Steven K. Krueger, Dept. of Atmospheric Sciences, U. of Calif., Los Angeles, "Observations and Modeling of Turbulence in Cumulus Clouds," May 6, 1988.

Julius London, U. of Colorado, "The Global Distribution of Ground-based Observed Cloudiness," April 28, 1988.

Larry Mahrt, Oregon State U., Corvallis, OR, "On the Stability of Stratified Shear Flow," and "A One-Dimensional Model of the Soil, Surface Energy Budget and Planetary Boundary Layer," July 6, 1989.

Bryant J. McAvaney, Bureau of Meteorology Research Center, Melbourne, Australia, "Use of the BMRC Atmospheric General Circulation Model for Greenhouse Modelling," November 2, 1989.

John Merrill, U. of Rhode Island, "Patterns and Processes of Aeolian Dust Transport," July 14, 1989.

Thomas Murphree, Dept. of Land, Air and Water Resources, U. of Calif., Davis, "Subtropical Mediation of Tropical-Extratropical Atmospheric Communication," February 10, 1989.

Josef Oberhuber, Max Planck Institute, Federal Republic of Germany, "Ocean General Circulation Modeling," August 4, 1989.

Harold D. Orville, Dept. of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, "Ice Phase Parameterizations for Cloud Models and Applications," May 26, 1988.

Alejandro Pares-Sierra, Scripps Institution of Oceanography, "The Seasonal and Interannual Variability of the California Current System: A Numerical Model, " June 12, 1989.

Thomas Phillips, Computer Sciences Corp., Silver Spring, MD, "Modeling the Impact of Sea Surface Temperature Anomalies on Seasonal Climate," May 19, 1989.

David A. Randall, Colorado State U., "Why is There a Diurnal Cycle of Precipitation over the Oceans?" December 20, 1988.

Steve Rutledge, Dept. of Atmospheric Sciences, Colorado State U., "Relationships between Lightning, Storm Dynamics and Cloud Microphysics," December 7, 1989.

M. P. Singh, Head, Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi, India, "Mathematical Models for Atmospheric Dispersion from Recent Industrial Accidents: -MIC at Bhopal, 1984; Oleum at Delhi, 1985," May 10, 1988.

Su-Tzai Soong, Dept. of Land, Air, and Water Resources, U. of Calif., Davis, "A Numerical Simulation of the Mesoscale Wind Pattern in California," October 31, 1988.

Roger Speed, D-Division, Lawrence Livermore National Laboratory, "Meteorite Impact as a Possible Source of Soot in the C-T Boundary Layer," April 14, 1988, (415) 423-8100.

Kenneth R. Sperber, SUNY, Stony Brook, "Southern Oscillation Simulation in Coupled Ocean/Atmosphere Global Climate Models," April 14, 1989.

Gregory R. Taylor, Calif. State U., Chico, "Entrainment and Mixing in Cumulus Clouds," October 20, 1989.

Hartmut Walter, Bundesgesundheitsanst, Institut for Strahlenhygiene, Neuherberg, Federal Republic of Germany, "Atmospheric Transport of Radionuclides after the Chernobyl Event: Problems and Possible Solutions," December 8, 1988.

Robert B. Wilhelmson, Dept. of Atmospheric Sciences, U. of Illinois, and National Center for Supercomputing Applications, Champaign, IL, "Recent Advances in the Simulation of Severe Storms in a Supercomputer Environment," April 26, 1988.

Michael Williams, U. of Michigan, "A Unified Theory of Aerosol Coagulation," July 13, 1988.

Appendix G. Summary of Modeling Capabilities

We have developed a wide variety of modelling capabilities in the course of our many research efforts. This section is divided into seven modeling categories. Each model is listed and briefly described under the category that best describes its primary application. The scientists currently having primary responsibility for each code are also listed; these individuals are not necessarily the developers of the model.

Species Transport and Diffusion Models

MATHEW/ADPIC Model

This three-dimensional particle-in-cell (PIC) model calculates the transport and diffusion of a puff or plume in a time-varying atmospheric boundary layer. ADPIC is based on the PIC concept, with the hydrodynamic aspect being replaced by a three-dimensional, mass-conservative, time-varying wind field provided by the MATHEW code. We have used this computer model to simulate particulate and gaseous concentrations, the deposition of particles with given size distributions, and rainout (from one or more sources) out to distances of several hundred kilometers. ADPIC calculations have been compared against measurements for many field-diffusion experiments, including the ASCOT program and for emergency and assessment response, such as the 1979 TMI incident, the subsequent Presidential Commission investigation, and the 1986 Chernobyl accident.

Contact: Rolf Lange

HMEDIC/HADPIC

HADPIC is a version of the ADPIC model modified to provide a capability to model transport and diffusion of pollutant clouds in the troposphere of the Northern Hemisphere using three-dimensional wind fields. These wind fields are constructed in the ARAC central facility from Air Force Global Weather Central gridded wind data. HMEDIC is a data-handling and interpolation code that processes the AFGWC gridded data, either analysis or forecast, into three-dimensional arrays. HADPIC provides as output the pollutant concentrations at selected regions over the Northern Hemisphere. The code was used to simulate the time and space evolution of the 1986 Chernobyl reactor accident.

Contacts: Rolf Lange, Thomas J. Sullivan, Robert P. Freis, Daniel J. Rodriguez

GRANTOUR Tracer Transport Model

GRANTOUR is a global atmospheric model that uses prescribed winds to transport species using a Lagrangian-sampler-parcel approach to calculate advection of tracers very accurately. The model can also calculate, if appropriate, scavenging (given precipitation rates), coagulation, dry deposition, mixing between air parcels, and radioactive decay. The model has been used to study the movement and dispersion of smoke and radionuclides in an unperturbed atmosphere (see also OSU/GRANTOUR General Circulation Model and LLNL/NCAR Community Climate Model). The model has also been modified to represent atmospheric chemistry (see GRANTOUR Chemistry and Aerosol Model).

Contacts: John J. Walton, Joyce E. Penner

Advection-Diffusion FEM Model

This two-dimensional code solves the advection-diffusion equation (for concentration, for example) in arbitrary geometry and in which a fixed velocity field is specified as input data. Either time-dependent or steady-state solutions are available. As a special case, the transient or steady diffusion equation can also be solved.

Contacts: Philip M. Gresho, Robert L. Lee

Tracer Trajectory Model

This model uses data on winds and temperature to calculate trajectories on an irregular, continental-scale grid. A specified number of parcels, injected at different times, locations, and heights, can be used to represent a tracer injection and can be followed over periods of several days to several weeks. Parcel trajectories may be followed for (1) constant height above terrain, (2) constant parcel potential temperature, or (3) constant parcel pressure. Dispersal of the tracer by eddy mixing (or diffusion) is not considered.

Contact: Ronald L. Baskett

CPS Model

This Gaussian, continuous-point-source (CPS) diffusion and deposition model is used in ARAC applications for initial response calculations. It has two modes of operation: (1) with one set of wind and stability inputs and (2) with up to one year of fifteen-minute or hourly averages. The model incorporates deposition velocity, plume rise, radioactive decay, terrain, and washout. In the multiline input mode, the user specifies whether the release is routine or accidental. The output consists of both average concentration and deposition contours, and contours for various probabilities that specific values will be exceeded.

Contact: Kevin T. Foster

Radionuclide Models

CAP Model

The Containment Atmosphere Physics (CAP) model capability simulates reactor-containment building scavenging processes. To be flexible and process-oriented, this simulation is based on methods of systems dynamics; i.e., if new physical processes seem important, the code allows for their easy insertion into its structure. It should, for example, be feasible and relatively easy to incorporate at least some of the important scavenging processes left out of currently used models. This effort requires both the development of the appropriate cloud-physics database and a simulation that realistically describes the scavenging processes inside a containment building when its equation of state is driven by gaseous releases from a melting core.

Contact: Ted F. Harvey

KDFOC2 Model

This versatile fallout model has been developed to assess complex civil defense and military effects issues. Large technical and scenario uncertainties require a fast, adaptable, time-dependent model to obtain technically-defensible fallout results in complex demographic scenarios. The KDFOC2 capability and other databases available in G-Division provide the essential tools for considering tradeoffs between various plans and features of different nuclear scenarios and for estimating the technical uncertainties inherent in the predictions.

Contacts: Ted F. Harvey, Leslie L. Edwards

GLODEP2 Model

The GLODEP2 model provides estimates of the surface deposition of worldwide radioactivity and the gamma-ray dose-to-man from intermediate and long-term fallout produced by nuclear explosions. The model is based on empirical relationships derived primarily from injection-deposition experience gained from the U.S. and the U.S.S.R. nuclear tests in 1958. If a nuclear power facility is destroyed (vaporized) and its debris behaves in the same manner as the radioactive cloud produced by the nuclear weapon that attacked the facility, the model can predict the gamma dose from this source of radioactivity. Empirically derived gamma dose relationships that account for meteorology, weathering, and terrain-roughness shielding at specific locations are included. As a comparison study, the gamma dose due to the atmospheric nuclear tests from the period of 1951–1962 has been computed, and results compare well with observations.

Contacts: Leslie L. Edwards, Ted F. Harvey

MISER Model

The MISER model treats mini-scale hydrology and groundwater transport of radionuclides from a geologic repository to the biosphere. The potential hazard and dose-to-man may be calculated for a limiting individual using well water of an average individual or population in a river-use system. The code solves a steady-state hydrology equation for an arbitrary network of one-dimensional flow-stream tubes. Conservation of water and D'Arcy's laws provide the system of hydrologic equations. A propagator method of solution is employed for nuclide transport. The results of the ORIGEN and BIODOSE codes are used to determine radioactive decay and river-use system doses. Monte Carlo techniques are applied, where appropriate, to account for measurement and spatial uncertainties. A 500-trial simulation, involving 54 stream tubes with eight parallel paths from a lower aquifer through the repository to the upper aquifer and the biosphere, required less than 2.5 min of CRAY-1 computer time.

Contacts: Ted F. Harvey, Leslie L. Edwards

Atmospheric Chemistry and Microphysics Models

One-Dimensional Chemical-Radiative-Transport Model

The one-dimensional chemical-radiative-transport model calculates globally averaged, vertical profiles of relevant trace gas concentrations in the troposphere and stratosphere. This model is a useful diagnostic and prognostic tool for studying chemical, radiative, and dynamical processes and interactions in the atmosphere. It has been used extensively for national and international investigations of the effects of potential chemical emission scenarios upon the ozone layer and for studies related to climate change. Modes of model execution include diurnally cycled or diurnally averaged, for time-dependent scenarios or rapidly obtained steady-state solutions. The model atmosphere extends from the ground to just above the stratopause (approximately 56 km) and is divided into 44 layers. The model chemistry includes approximately 130 chemical reactions among 40 species. The radiative treatment for photolysis reactions includes the effects of multiple scattering. Changes in radiatively active trace-gas concentration can be used to obtain new stratospheric-radiative-equilibrium temperatures. Transport processes in the one-dimensional model are simulated by prescribed diffusion coefficients.

Contacts: Donald J. Wuebbles, Peter S. Connell, Keith E. Grant, Douglas E. Kinnison

Two-Dimensional Chemical-Radiative-Transport Model

The two-dimensional model calculates the zonally averaged, time-dependent concentrations of relevant tropospheric and stratospheric trace gases as they vary with latitude, altitude, and season. This model currently uses a grid with 16 latitude zones and 18 vertical layers, although a much-higher-resolution version is in preparation. It includes approximately 100 reactions among thirty species, including 27 photolysis reactions. Diabatic winds are calculated using model-derived-radiative and latent-heating rates, assuming prescribed seasonally varying initial temperatures. These prescribed temperatures are appropriate for ambient trace-gas concentrations. For chemical perturbation scenarios, either temperatures or diabatic winds can be varied as radiatively active trace species are perturbed from their ambient concentrations.

Contacts: Donald J. Wuebbles, Peter S. Connell, Keith E. Grant, Douglas E. Kinnison

GRANTOUR Chemistry and Aerosol Model

The GRANTOUR model calculates the three-dimensional distribution of gas-phase and aerosol-phase species using a Lagrangian formulation. Current applications use simplified chemical interactions to describe the global distributions of reactive nitrogen and sulfur species. These are being extended to treat more complete chemical interactions. The model is also able to describe simple aerosol interactions including the effects of aerosol coagulation, the formation of aerosol particles from the gas-phase oxidation of sulfur compounds, and the effects of aerosol population on cloud droplet number distributions. In most applications, the wind and precipitation fields from the NCAR CCM global climate model are used to drive the species transport and removal, although the model has been linked to other climate models as well. The model can also be run interactively with the NCAR climate model to study the effects of aerosols on climate and climate change.

Contacts: Joyce E. Penner, John J. Walton, Cynthia S. Atherton

Multi-Layer Air Quality Model

This Eulerian code is a successor to the Livermore Regional Air Quality Model (LIRAQ) that represented boundary-layer air-pollution in two dimensions. This model was developed to describe the long-range, multi-day transport and chemical interactions of air pollutants in which pollutants may be isolated overnight in an elevated layer and reincorporated into the mixed layer the following day. This code uses a split-operator method to solve the three-dimensional transport and chemical kinetics equations for air pollutant concentrations. A highly accurate upstream-differencing method with an antidiffusion correction step has been adopted to describe the transport of pollutants in order to preserve positive species concentrations without the need for an artificial smoothing technique that would add artificial diffusion. The code has been developed for use with an arbitrary number of vertical layers, although only a two-layer version has been implemented to date. In the two-layer version, one layer is used to describe the transport of pollutants below the inversion and one is used to describe the transport above the mixed layer; the model accounts for the deepening of the mixed layer and for the mixing of air from above during the afternoon. Pollutant-source inventories, topography, and meteorology for the region of interest must be specified as input to the model. In the current version, mass-consistent wind fields are first developed in the MATHEW model and then processed for the layer-average winds needed in the Multi-Layer Air Quality Model. The model has recently been applied to study the coupling of the Monterey and Bay Area air basins.

Contacts: Joyce E. Penner, Peter S. Connell

Atmospheric Kinetics Model

This model is used for detailed studies of the chemical and photochemical kinetics (no transport) of the troposphere and stratosphere. It uses advanced mathematical methods to study the kinetics of a well-mixed cell, including the effects of solar absorption for photodissociation processes. This model has been used for evaluating the sensitivity of reaction mechanisms to deficiencies in knowledge of reaction rates, quantum yield, reaction ensemble, solar constant, and reactant concentrations. The model has also been useful for studying the feasibility of using reduced-reaction sets in more complex atmospheric models.

Contacts: Donald J. Wuebbles, Joyce E. Penner, Peter S. Connell

Atmospheric Kinetics and Aerosol Nucleation Model

This model is used for detailed studies of the chemical and photochemical interactions of species leading to the formation of condensable products in the atmosphere. The condensable products may form new aerosol particles (nucleation) or may condense on pre-existing particles. The aerosol number concentration and mass mean diameter are calculated for two separate aerosol modes. The model has been useful for studying the atmospheric conditions leading to new particle formation and the composition of aerosols in the atmosphere.

Contact: Joyce E. Penner, Sonia Kreidenweis

CAMP Model

The CAMP computer code numerically solves the atmospheric microphysical equations in a well-mixed spherical or plume-like parcel of air, water vapor, liquid water, and aerosols. The aerosols may be of differing compositions of water-soluble and insoluble materials. The parcel may be pseudo-adiabatic, where the dynamics are driven by the buoyancy forces acting on a background sounding, or may be based on a specified "trajectory" for which the dynamics are determined by a cloud-scale dynamics code. The parcel may entrain background aerosols and drops. Given an aerosol-number density distribution and/or a drop-number density distribution, the code solves for the time evolution of the distributions as well as for the parcel temperature and saturation. The microphysical processes included are: condensation/evaporation of water vapor, nucleation of aerosols to form drops, aerosol coagulation, drop coalescence, interstitial aerosol collection by drops, and drop break-up—all on spherical particles. The model does not yet consider ice processes, which may be important in some applications.

Contact: Leslie L. Edwards, Catherine Chuang

Aerosol Coagulation Model

This model solves the kinetic coagulation equation, which determines the evolving size distribution of an assemblage of aerosol particles. The model accounts for the collision of aerosol particles due to Brownian motion, turbulent motion, laminar-shear flow, and sedimentation. Dispersion of the aerosol is accounted for by specification of a dilution-time constant, which may be specified from observations or calculation. A submodel is available to calculate the absorption and scattering cross section of the aerosol. The model has been applied as a Lagrangian-parcel model to describe the evolution of the size distribution and optical characteristics of smoke and dust particles after a nuclear war.

Contact: Joyce E. Penner

CUMSCAV Model

This cloud-scavenging model is used to estimate the removal of pollutants or radioactivity from the atmosphere because of scavenging by convective clouds. The cloud dynamics and microphysics for this model come from the Rand Corporation's Cumulus Dynamics Model, which is two-dimensional in either axial or rectilinear symmetry and uses a bulk microphysics parameterization. Transport of pollutant material in the cloud's field of motion and a compatible bulk microphysical scavenging parameterization have been incorporated to complete the model. The model has been used not only to calculate scavenging by natural convective clouds, but also for estimating self-induced rainout from nuclear weapons at Hiroshima and Nagasaki.

Contact: Charles R. Molenkamp

STRATSCAV Model

This model is based on a module used in the 2BPUFF transport and diffusion model. It calculates the scavenging and deposition of pollutant particles as they move through a region of widespread stratified precipitation. The precipitation is assumed to be horizontally homogeneous, implying that a one-dimensional cloud model can be used to derive the vertical distribution of clouds, rain, and snow. These hydrometeors then interact with the pollutant particles to scavenge, redistribute, and deposit them. A surface-based grid gives the horizontal distribution of the removed pollutant.

Contact: Charles R. Molenkamp

Radiative Transfer Models

SWPAK

This model computes upward and downward ultraviolet and visible radiation fluxes given atmospheric vertical profiles of pressure, temperature, and concentrations of O_2, O_3, and NO_2. The calculated fluxes can be used by chemical-radiative-transport models to calculate layer heating rates or, with additional driver routines, photodissociation rates. The formulation of this model accounts for multiple scattering and allows inclusion of clouds and aerosols as well as absorbing gases. The solar spectrum and pertinent absorption cross sections are divided into 148 wavelength bins between 133.75 and 730 nm. Advantage is taken of each wavelength bin constituting an independent radiation transfer problem to allow the coding to vectorize over wavelength bins when compiled on the Cray-1 or Cray-XMP. For each plane-parallel vertical layer, the scattering and absorption of diffuse incident radiation is treated using the Sagan and Pollack two-stream algorithm. Scattering and absorption from the direct solar beam is treated using the delta-Eddington approximation. The effects of the separate layers are combined using the adding technique.

Contact: Keith E. Grant

Wide-Band IR Model for Cooling Rates from CO_2, H_2O, and O_3

The initial version of this model was obtained from Harshvardhan, et al. ["A Fast Radiation Parameterization for Atmospheric Circulation Models," *J. Geophys. Res.*, **92** (D1), 1009–1016, 1987]. The model is based on the far-wing scaling approximation and k-distribution approaches described in a series of papers by M.-D. Chou ["Broadband Water Vapor Transmission Functions for Atmospheric IR Flux Computations," *J. Atmos. Sci.*, **41** (10) 1984]; M.-D. Chou and A. Arking ["Computation of Infrared Cooling Rates in the Water Vapor Bands," *Am. Met. Soc.*, 855, 1980]; M.-D. Chou and L. Kouvaris ["Monochromatic Calculations of Atmospheric Radiative Transfer due to Molecular Line Absorption," *J. Geophys. Res.*, **92** (D3), 4047–4055, 1986]; and M.-D. Chou and L. Peng ["A Parameterization of the Absorption in the 15 μm CO_2 Spectral Region with Application to Climate Sensitivity Studies," *J. Atmos. Sci.*, **40** (9), 1983]. The model was developed to meet requirements for use in GCMs. It is computationally efficient in its basic algorithm, plus it is written to vectorize over separate vertical columns. The original model has required modifications to obtain sufficient accuracy at stratospheric pressure less than 3 mb.

Contact: Keith E. Grant

Narrow Band IR Model

The initial version of this model was obtained from David Kratz (NASA Goddard) with parameters for CO_2, H_2O, O_3, CH_4, and N_2O. Parameters for CFCs (including temperature dependence) await detailed spectroscopic measurements. Restructuring and vectorization at LLNL has decreased the running time on a Cray-XMP to about four seconds using 31 vertical levels and an eight-point Gaussian integration over angle of propagation. Further reductions in running time are likely via parallelization. The narrow-band model is an extremely useful tool for analysis of the radiative forcings from changes in trace-gas-concentration vertical profiles. However, even with vectorization, computer time requirements limit the usefulness of the narrow-band model as an interactive part of GCMs and chemical-radiative-transport models.

Contact: Keith E. Grant

Atmospheric Dynamics Models

FEM3 and FEM3A Dense-Gas-Dispersion Models

These codes were developed primarily to simulate the atmospheric dispersion of heavier-than-air gas and liquid releases. A modified Galerkin finite-element method was employed to solve the time-dependent conservation equations of mass, momentum, energy, and species of the dispersed material together with the ideal gas law for the density of the mixture. A generalized anelastic approximation was invoked to preclude sound waves and yet allow large-density variations in space and time. Turbulence is parameterized via a K-theory submodel and heat transfer from the ground surface into the vapor cloud are also accounted for. Both codes can solve two- and three-dimensional problems, including treatment of variable terrain and finite-duration or continuous releases. In FEM3, an option exists for solving the Boussinesq equations as well. In FEM3A, instantaneous sources and obstructions are also treated. In addition, a phase-change submodel is available for handling the phase transitions (between vapor and droplets) of the dispersed material.

Contacts: Stevens T. Chan, Philip M. Gresho

FEM-PBL

This model, derived from FEM3, has been developed to simulate planetary boundary layer flow over complex terrain. It calculates the spatial and temporal distribution of velocity, pressure, potential temperature, and mixing ratios of liquid water, water vapor, and an inert tracer in two or three dimensions. The nonhydrostatic, Boussinesq equations with constant rotation form the basic dynamical framework of the model. Boundary layer turbulence is parameterized via one of three K-theory models: an O'Brien cubic parameterization, a local Richardson number dependent parameterization, or a specified constant K. The model contains a nonlinear phase-change model to describe the effects of evaporation and condensation of water. As in FEM3, multilinear velocity, piecewise-constant pressure finite elements are used in space, while a modified, explicit forward-backward Euler scheme is used to advance the spatially discrete equations in time. This combination of methods allows faithful representation of complex terrain, easy implementation of variable grids, and efficient performance.

Contacts: John M. Leone, Jr., Robert L. Lee

SABLE

This model has been developed to model atmospheric boundary layer flows over moderate terrain on horizontal scales of a few hundred to 1000 kilometers. The hydrostatic, anelastic equation set with constant rotation forms the dynamical basis for the model. Boundary layer turbulence is parameterized via one of three K-theory models: an O'Brien cubic parameterization, a local Richardson number dependent parameterization, or a specified constant K. The model contains a surface energy budget based on the soil slab model of Blackadar. Multilinear finite elements are used in space, while a semi-implicit scheme is used to advance the spatially discrete equations in time. This combination allows faithful and efficient representation of the terrain, easy implementation of variable grids, and accurate and cost-effective performance.

Contacts: John M. Leone, Jr., Stevens T. Chan

FEM Nonhydrostatic Planetary-Boundary-Layer Model

This code, derived from FEM3, calculates the spatial and temporal distribution of velocity, pressure, potential temperature, and the mixing ratios of liquid water, water vapor, and an inert tracer in two or three dimensions. With the addition of the constant-rotation Coriolis force and a nonlinear phase-change model to describe the effects of evaporation and condensation, the Boussinesq equations constitute the model equation set. As in FEM3, multilinear velocity, piecewise-constant pressure elements are used in space, while the explicit forward-backward Euler scheme is used to advance the spatially discrete equations in time.

Contacts: John M. Leone, Jr., Robert L. Lee

FEM Hydrostatic Mesoscale Model

This newest of the finite-element-based models is a spinoff from all of the earlier ones. It has been designed to provide a new capability in which both two- and three-dimensional computations over reasonably complex terrain can be performed in much less central processing unit (CPU) time than with the earlier models. This is done by solving a simpler and more restrictive set of model equations in which hydrostatic equilibrium is assumed to exist. A version of this new model will be designed to operate on the ARAC computer system (VAX) and to thus assist in emergency response by providing actual forecast winds. A research version will be used in a simulation mode and will be continuously upgraded in its physical and mathematical capabilities.

Contact: John M. Leone, Jr., Stevens T. Chan

CSU Mesoscale Model

We are using the Colorado State University (CSU) Mesoscale Model developed by R. Pielke and his students to simulate a variety of terrain and surface-forced mesoscale flows. This model is a hydrostatic, incompressible, primitive equation model; it includes topography and a detailed boundary-layer parameterization. The flows are usually driven by surface heating, which is calculated by balancing the surface-energy budget at each grid point. Atmospheric heating by absorption and emission of long- and short-wave radiation is also included. The model is three-dimensional, but it can be run in a two-dimensional, rectilinear mode. For our applications, the CSU Mesoscale Model has been enhanced by allowing clouds and fog to form in saturated regions and by greatly improving the long-wave radiation parameterization.

Contact: Charles R. Molenkamp

OCTET: Dynamical and Microphysical Plume, Storm, and Mesoscale Numerical Simulation System

The OCTET Simulation System consists of eight numerical models that are applicable to a large number of atmospheric phenomena and spatial scales, ranging from dry mesoscale circulations, to tornadoes, to the interactions of aerosols with liquid and frozen precipitation inside violent thunderstorms. The OCTET system uses the nonhydrostatic, compressible, three-dimensional dynamic framework of the Klemp-Wilhelmson storm model. The system has a modular structure, and new modeling capabilities are continuously being added. The simplest model in the OCTET system has only six prognostic variables; the most complex model has over twenty prognostic variables. The eight models in the OCTET system are capable of simulating the nonhydrostatic and hydrostatic dynamics and the microphysical processes in:

1. Dry mesoscale circulations;
2. "Warm" precipitating, convective and stratiform clouds; and warm, moist, mesoscale circulations;
3. "Cold" ice-bearing (ice crystals, snow, graupel, and hail), convective and stratiform clouds; and severe storm circulations including squall lines, gust fronts, microbursts, low-level wind shears, and tornadoes;
4. Lightning generation in severe, electrified storms and storm complexes (projected capability, not operational in 1990);
5. Dry smoke plumes (e.g., from forest fires or from burning cities in postnuclear-exchange environments); and aerosol transport and diffusion in dry mesoscale circulations;
6. Smoke plumes in warm, moist atmospheres with condensation, liquid precipitation, and smoke scavenging and removal; and aerosol transport, diffusion, and hydrometeor-aerosol interactions in warm, moist, mesoscale circulations;
7. Smoke plumes in cold, moist atmospheres with condensation, freezing, liquid and solid precipitation, and smoke scavenging and removal; and aerosol transport, diffusion, and hydrometeor-aerosol interactions in cold, moist, mesoscale circulations;
8. Electrified smoke plumes; large, intense smoke plumes that interact with fire-forced, electrified, ice-bearing clouds; and aerosol transport, diffusion, and hydrometeor-aerosol and aerosol-aerosol interactions in mesoscale circulations in electrified atmospheres (projected capability, not operational in 1990).

The OCTET system is operational on the Cray-1, Cray-2, and Cray X-MP computers using both the CFT and CIVIC compilers.

Contact: Michael M. Bradley

Cloud/Mountain Model

This model was originally designed for the numerical simulation of convective, precipitating storms over complex terrain. It is also capable of simulating stratiform, precipitating orographic storms, hydrostatic and nonhydrostatic mountain waves, and the dynamics and microphysics of smoke plumes from intense fires. The model is two-dimensional, time-dependent, Eulerian, nonhydrostatic, and fully compressible. It is based on the three-dimensional cloud model of J. B. Klemp and R. B. Wilhelmson ["The Simulations of Three-Dimensional Convective Storm Dynamics," *J. Atmos. Sci.*, **35**, 1070–1095, 1978], but differs from their model in several major ways: It is formulated in terrain following coordinates, it utilizes a Rayleigh sponge to simulate a radiative upper-boundary condition, it uses different the turbulence parameterization and boundary conditions, it includes the complete pressure equation, and it uses no linearization to simplify the equations.

Contact: Michael M. Bradley

SLAB Dense-Gas-Dispersion Model

This code simulates the atmospheric dispersion of denser-than-air releases. The types of releases treated by the model include a ground-level evaporating pool, an elevated horizontal jet, a stack or vertical jet, and an instantaneous volume source. Except for the evaporating pool source, which is assumed to be all vapor, each of the other sources may be a two-phase mixture of vapor and liquid droplets. Source duration may be any finite length of time. SLAB simulates atmospheric dispersion by solving spatially averaged forms of the conservation equations of mass, momentum, energy, and species, along with cloud width and length equations and the equation of state, using the Runge-Kulta method. The code is one-dimensional with downwind distance being the independent variable; however, the full three-dimensional concentration distribution is determined by using similarity profiles based on the calculated cloud height, length, and width. Within SLAB's mathematical framework of heavy-gas dispersion, there is a natural progression toward neutrally buoyant trace-gas dispersion allowing for calculations down to the lowest-desired concentration levels. The main advantage of SLAB over more complex heavy-gas models is its low computing cost. Typical simulations require only a few seconds on a CDC 7600 computer or a few minutes on an IBM microcomputer.

Contact: Donald L. Ermak

Laser Isotope Separation Model

Developed in support of the Atomic Vapor Laser Isotope Separation program at LLNL, this model solves the two-dimensional Boussinesq equations in either a Cartesian or axisymmetric coordinate system, using bilinear velocity, piecewise-constant pressure elements in space, and either a forward-backward Euler or semi-implicit scheme in time. While the partial differential equations solved are the same as those in the FETISH model, this newer code, which is a useful blend of finite elements and finite differences, is more cost-effective in most practical cases.

Contacts: Stevens T. Chan, Philip M. Gresho

FETISH Model

This two-dimensional code is a general-purpose package that can be used to solve the two-dimensional, steady or time-dependent Stokes, Navier-Stokes, or Boussinesq equations in either Cartesian or axisymmetric coordinate systems—either of which allows complex domains to be modeled. It uses the Galerkin finite-element method in either mixed or penalty form for the spatial discretization with a choice of quadrilateral elements. It uses either the trapezoid rule or backward Euler for the time discretization. The systems of equations are linearized via Newton's method, and the resulting linear systems are solved by means of the frontal method.

Contacts: Philip M. Gresho, Robert L. Lee

Hydrostatic FEM Model

This code solves the two-dimensional, Boussinesq equations of motion, taking advantage of the efficiency (in computational costs) of the hydrostatic assumption. It uses both the Galerkin and least squares finite-element methods for the spatial discretization and a two-step (near-trapezoid-rule) time-integration scheme. When the hydrostatic assumption is valid, this code is more cost-effective than FETISH. A modified version of this code is being used at Iowa State University.

Contacts: Stevens T. Chan, Philip M. Gresho

Global Climate Models

LLNL/NCAR Community Climate Model

The National Center for Atmospheric Research (NCAR) general circulation model, CCM1, has been transferred to Livermore and adapted to the LLNL computer systems. Its parameterization of solar radiation has been replaced with a two-stream, delta-Eddington model, which uses the cloud overlap scheme of Morcrette and Fouquart. Cloud optical depth is expressed in terms of cloud droplet number concentration and cloud liquid-water content. The cloud liquid-water content is diagnosed from the simulated condensation rate. The cloud droplet number is either prescribed or predicted through coupling with the GRANTOUR aerosol transport model. The direct radiative effects of aerosols can also be accounted for through coupling with GRANTOUR.

Contacts: Curtis C. Covey, Steven J. Ghan, Karl E. Taylor

LLNL/Oregon State University General Circulation Model

The modified LLNL/OSU GCM is being used as a tool for understanding climate model validation with satellite data and for developing a methodology for model intercomparison. The model has been used to explore causes of the differences among climate models, focusing specifically on differences in cloud forcing and cloud properties. A version of the model coupled to a two-level mixed-layer ocean model has been used in parallel integrations with both normal and doubled atmospheric CO_2. The results of these simulations are being used to determine the seasonal and geographical distributions of CO_2-induced climate changes, including the behavior of low-frequency phenomena such as the ENSO.

Contact: Gerald L. Potter

ECMWF Global Atmospheric Model

Through a cooperative agreement with the European Centre for Medium Range Weather Forecasts (ECMWF), the operational (cycle 32, 19-level) global atmospheric model is being used by the Program for Climate Model Diagnosis and Intercomparison (PCMDI). The model contains advanced radiation, cloud, and surface hydrology packages, and when run with assimilated, synoptic, initial data and observed sea-surface temperature, is probably the world's most accurate numerical weather prediction model over the 1 to 10 day range. The model is initially being run over several years in the four (spectral) resolutions T21, T42, T63, and T106 in order to examine the effects of resolution on simulated climate and climate processes.

Contacts: W. Lawrence Gates, Gerald L. Potter

Oregon State University/GRANTOUR General Circulation Model

The GRANTOUR species-transport model and the OSU/LLNL GCM have been interactively coupled so that the species concentrations in the GRANTOUR model may perturb the radiative calculation in the OSU/LLNL GCM and so that the winds and precipitation in the OSU/LLNL GCM control the transport and scavenging of species in GRANTOUR. This model has been used extensively to study the potential climatic effects of post-nuclear-war smoke injections. Another version of GRANTOUR treats the global wet and dry deposition of nitric acid resulting from global sources of NO_x and a simple chemistry. This model is run in its uncoupled mode with OSU/LLNL GCM meteorology.

Contacts: Steven J. Ghan, John J. Walton

Two-Dimensional Climate Model

A new zonally averaged climate model has been developed for coupling with two-dimensional models of ocean circulation and stratospheric chemistry. Poleward and vertical transport of heat, moisture, and momentum by large-scale eddies have been parameterized using mixing length concepts based on conservation of potential temperature, water vapor, and potential vorticity. The hydrological cycle is explicitly simulated, including storage of soil moisture and snow. Land and ocean surfaces are distinguished in terms of their heat capacity and moisture storage capacity. The ocean is presently represented as a simple mixed-layer slab. Both the diurnal and annual cycle in solar declination can be accounted for. Sea ice is presently crudely diagnosed in terms of ocean temperature. Cloud-radiation feedbacks are treated through predictions of cloud cover and cloud liquid water and their impact on solar and terrestrial radiation.

Contacts: Karl E. Taylor, Steven J. Ghan

Statistical-Dynamical Climate Model

The Livermore Statistical-Dynamical Climate Model (LSDM), also referred to as ZAM2, is a two-dimensional, Eulerian, thermodynamic model of Earth's atmosphere-surface-ocean system in the meridional plane. The model considers a moist atmosphere and includes such effects as solar and infrared radiation, variable cloudiness, precipitation, surface interactions, the variable extent of snow cover and sea ice, and mountains. The seasonal version of the model includes a well-mixed layer and prescribed meridional heat fluxes in the ocean layer. The model has been used to test the response to increased atmospheric CO_2, arctic soot, volcanic aerosol injections, and other perturbations.

Contacts: Michael C. MacCracken, Karl E. Taylor

Simplified Climate Model for Secondary School Education

This "toy" climate model is available for educational purposes. It is based on highly simplified, radiative transfer theory and has been tuned to give reasonably accurate estimates of globally averaged surface temperatures. The model currently runs on Macintosh computers in an interactive fashion that allows students to explore the influence on climate of such factors as CO_2 concentration, cloud cover, albedo, and water vapor feedback. A speculative, semi-empirically based, sea-level model is also included.

Contact: Karl E. Taylor

Oceanic General Circulation Models

Global Eddy-Resolving Model

This model, developed by A. Semtner and R. Chervin, is a direct descendant of the first oceanic GCM developed at the NOAA Geophysical Fluid Dynamics Laboratory over 20 years ago. In much the same way as atmospheric GCMs, this model calculates temperature, pressure, salinity, and current velocity on a three-dimensional global grid, given initial and boundary (surface forcing and topography) conditions. Semtner and Chervin rewrote the GFDL code for efficient execution on parallel-processing vector supercomputers, allowing for the first time a high-resolution version that includes the so-called mesoscale oceanic eddies while retaining global coverage. The Semtner-Chervin code is now being transfered to the National Energy Research Supercomputer Center (NERSC) computers at Livermore.

Contact: Curtis C. Covey

Isopycnic-Coordinate Model

This model, developed by J. M. Oberhuber of the Max Planck Institute ["Simulation of the Atlantic Circulation with a Coupled Sea Ice–Mixed Layer–Isopycnal General Circulation Model," submitted to the *J. Phys. Oceanography*], uses density as a vertical coordinate, an advantage for oceanic GCMs because most of the oceans' mixing processes take place along surfaces of constant density. This model also incorporates submodels of the oceanic, upper mixed layer and sea ice (with rheology). The domain is easily adjustable from basin-wide to global. An implicit time-differencing scheme allows time steps as long as two days for 3° resolution. The model is now being run at NERSC in cooperation with Tim Barnett and Arthur Miller at the Scripps Institution of Oceanography.

Contact: Curtis C. Covey

Ocean General Circulation Model

This model, developed by J. Han at Oregon State University and used in coupled atmosphere-ocean simulations by W. L. Gates, et al. [*Coupled Ocean-Atmosphere Models*, Elsevier, 1985], is a comprehensive six-level dynamical model of the global ocean circulation, with the option of an imbedded mixed layer. This model calculates the three-dimensional temperature, salinity, current and sea-ice distribution in response to prescribed surface forcing and bottom orography in much the same manner as the similar ocean models at GFDL. In its present configuration, this model has a horizontal resolution of 4° latitude and 5° longitude, and requires about 60 minutes to simulate one year's time on a CRAY-1 computer with a time step of 1 hour.

Contact: W. Lawrence Gates

Upper Ocean Model

This model, developed by D. Pollard at Oregon State University [*Performance of an Upper Ocean Model Coupled to an Atmospheric GCM: Preliminary Results*, Climatic Research Institute, Report 31, Oregon State University, Corvallis, OR, 1982] and used with a coupled atmospheric model in extended simulations for both normal and doubled CO_2 by W. L. Gates and G. L. Potter at LLNL, is a two-layer model of the upper ocean. This model calculates the horizontal current and temperature in a layer of variable depth representing the surface mixed layer and in an underlying layer (also of variable depth) representing the thermocline, with parameterized entrainment at their interface; sea-ice is calculated under the constraint of prescribed salinity. In its present configuration, this model has a horizontal resolution of 4° latitude and 5° longitude, and requires about 10 minutes to simulate one year's time on a CRAY-1 computer with a time step of one hour.

Contact: W. Lawrence Gates

Appendix H. Acronyms and Abbreviations

Acronym	Meaning
1-D	One-Dimensional
2-D	Two-Dimensional
3-D	Three-Dimensional
AAAR	American Association for Aerosol Research
ADPIC	Atmospheric-Diffusion Particle-in-Cell
AEC	U.S. Atomic Energy Commission
AFGWC	Air Force Global Weather Central
AGU	American Geophysical Union
AMS	American Meteorological Society
ANATEX	Across North America Tracer Experiment
ANS	American Nuclear Society
APCA	Air Pollution Control Association
API	American Petroleum Institute
ARAC	Atmospheric Release Advisory Capability
ARM	DOE's Atmospheric and Radiation Measurement Initiative
ASCOT	DOE's Atmospheric Studies in Complex Terrain program
ASME	American Society of Mechanical Engineers
AWMA	Air and Waste Management Association
BAAQMD	Bay Area Air Quality Management District
CAP	Containment Atmosphere Physics
CAPTEX	Cross-Appalachian Tracer Experiment
CCM1	National Center for Atmospheric Research/General Circulation Model, version 1
CEC	Commission of European Communities
CHAMMP	DOE's Computer Hardware, Advanced Mathematics, and Model Physics Initiative
CMA	Chemical Manufacturers Association
CPS	Continuous-Point-Source
CSU	Colorado State University
DNA	Defense Nuclear Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DP	DOE/Office of Defense Programs
ECMWF	European Centre for Medium Range Weather Forecasts
EH	DOE/Office of Environmental Safety and Health
EPA	Environmental Protection Agency
ER	DOE/Office of Energy Research
FAA	Federal Aviation Administration
FE	DOE/Office of Fossil Energy
FEM	Finite-Element Modeling
FEM3	Three-dimensional Finite Element Model
FRERP	Federal Radiological Emergency Response Plan
FRMAP	Federal Radiological Monitoring and Assessment Program
FY	Fiscal Year

G-Division	Atmospheric and Geophysical Sciences Division
GCM	General Circulation Model
GPP	General Plant Projects
GRANTOUR	Lagrangian Parcel Advection Code
GRI	Gas Research Institute
IAEA	International Atomic Energy Agency
IAMAP	International Association of Meteorology and Atmospheric Physics
IBM	International Business Machines
ICRCCM	Intercomparison of Radiative Codes in Climate Models
ICSU	International Council of Scientific Unions
InCoR	University of California Institute for Collaborative Research project with LANL and the Scripps Institution of Oceanography
INSRP	DOE/DOD/NASA Interagency Nuclear Safety Review Panel
IR&D	LLNL's Institutional Research and Development
J-Group	Liquefied Gaseous Fuels Program
JANNAF	Joint Army-Navy-NASA-Air Force panel
JOWOG	U.S.-U.K. Joint Working Group
LANL	Los Alamos National Laboratory
LGF	Liquefied Gaseous Fuels
LIRAQ	Livermore Regional Photochemical Air Quality Model
LLNL	Lawrence Livermore National Laboratory
LNG	Liquefied Natural Gas
M/A	MATHEW/ADPIC
MATHEW	Regional Diagnostic Flow Model
NAPAP	National Acid Precipitation Assessment Program
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NATO ASI	North Atlantic Treaty Organization Advanced Study Institute
NATO/CCMS	North Atlantic Treaty Organization Committee on Challenges of Modern Society
NCAR	National Center for Atmospheric Research
NERSC	National Energy Research Supercomputer Center
NOAA	National Oceanic and Atmospheric Administration
NR	Naval Reactors
NRC	Nuclear Regulatory Commission or National Research Council
NTS	Nevada Test Site
OAC	DOE/Office of Arms Control
OCONUS	Off or Outside the Continental U.S.
OECD	Organization for Economic Cooperation and Development
OGCM	Oceanic General Climate Model
OHER	DOE/Office of Health and Environmental Research
OMA	DOE/Office of Military Applications
OSU	Oregon State University
PACLIM	Pacific Climate Conference
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PE	DOE/Office of Policy, Planning, and Analysis
PIC	Particle-in-Cell

PRC	People's Republic of China
RPP	Reactor Product Program
SIAM	Society for Industrial and Applied Mathematics
SLAB	One-dimensional Dense-Gas Dispersion Model
STF	Spill Test Facility
SUNY	State University of New York
TMI	Three Mile Island
UARS	Upper Atmosphere Research Satellite
UASG	Unclassified Atmospheric Sciences Group report
UK/MOD	United Kingdom Ministry of Defense
UNEP	United Nations Environment Programme
VAX	Digital Equipment Corporation computer system
WMO	World Meteorological Organization
WSR	Weapons Special Research

END

DATE FILMED

12 / 05 / 90