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PROGRAM REPORT — FY 1974
ATMOSPHERIC AND GEOPHYSICAL SCIENCES DIVISION
PHYSICS DEPARTMENT

October 1, 1974

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Contents

ABSTRACT

The FY 1974 research program conducted by the Atmospheric and Geophysical Sciences Division and supporting segments at Lawrence Livermore Laboratory is reviewed briefly. Unique numerical modeling capabilities in use and under development are described. Specific projects are described together with an indication of significant findings of the work. Prospects for FY 1975 include the extension of existing work and broader application of the division's capabilities.

INTRODUCTION

Lawrence Livermore Laboratory (LLL) has participated in atmospheric and geophysical science research for many years. At first this activity was associated with the nuclear weapons program and examined such areas as the radioactive fallout produced by nuclear experiments in the atmosphere and plutonium contamination resulting from accidents involving nuclear weapons. Later the interest expanded to the study of theoretical geophysical hydrodynamic methodology. Applied research in the ecological effects of underground Plowshare nuclear explosions was also pursued. As a result of these activities, the Laboratory developed a broad base of experience and technical talents in the many fields necessary for understanding and solving atmospheric and geophysical problems for different classes of pollutants and sources. In particular, LLL now possesses a proven multidisciplinary team with capabilities in numerical modeling of physical, chemical, and transport processes in the environment on urban, regional, continental, and global scales.

The main instrument for accomplishing this work at LLL rests with the Atmospheric and Geophysical Sciences Division (G-Division) in the Physics Department. This organization was established in 1973 to focus the Laboratory's participation in the national efforts in this field. Formed from a nucleus of researchers in the Fluid Mechanics Group of the Earth Sciences Division and the Hydrodynamics Group of the Theoretical Physics Division, the new organization has responsibility for an integrated Laboratory program in the atmospheric and geophysical sciences for both the Atomic Energy Commission (AEC) and other agencies.

LLL MODELING CAPABILITIES

The division's research includes the study of atmospheric processes; the transport, diffusion, and chemical transformation of conventional or radioactive pollutants; and resultant effects upon the environment. Emphasis is on numerical simulation and analytical techniques. Unique modeling capabilities of the division are listed below.

1. ZAM2 is a two-dimensional, Eulerian thermohydrodynamic model of the earth's surface-atmosphere system in the meridional plane. The model considers a moist atmosphere and includes such effects as solar and longwave radiation, variable cloudiness, precipitation, trace species balances, surface interactions, variable sea ice extent, and mountains. The model is relatively fast running, requiring several hours of 7600 time to simulate one year of terrestrial climate.[1,2]

2. 2BPUFF is a two-dimensional, axially symmetric, Lagrangian code for calculating the anisotropic diffusion of fine particles of gases in a frame of reference moving with the center of the cloud of particles or gas. The diffusion coefficients can be time dependent. An Eulerian grid is used on the earth's surface to keep track of the cloud position and to provide the framework for bookkeeping on air concentrations during the passage of the moving cloud.[3,4]

3. The LLL regional air quality model (LIRAQ) is a two-dimensional, time-dependent grid model which utilizes prescribed meteorological and source emission data to provide measures of the regional air quality in the topographically complex San Francisco Bay Area. One existing version emphasizes transport of nonreacting species on a relatively fine grid while a second version now being developed uses a modified version of Gear's technique for solving large sets of stiff ordinary differential equations to treat evolution of photochemical pollutants.[5,6]

Models 4, 5, and 6 were developed for use in the numerical modeling of regional pollution from nuclear sources. This project is supported by the Division of Biomedical and Environmental Research of the AEC.

4. MACAW is a three-dimensional wind field model which accepts spacial and temperal measurements of winds and heights of inversion bases above topography as input data. These measurements are adjusted to provide fluxes that are mass consistent within a grid square. Topography in the region of interest plays a role in channeling the adjusted flow field. Output from this model is used as input for LIRAQ.[6,7]

5. A three-dimensional particle diffusion code (ADPIC) has been developed to calculate the transport and diffusion of a puff or plume in a transient atmospheric boundary layer. The model is based on the Particle-in-Cell (PIC) concept with the hydrodynamical aspects of the conventional PIC deleted. This code is intended to supplement the 2BPUFF code by predicting cloud shape, as well as concentrations, at early and late times in stratified shear flow.[8]

6. A flexible, three-dimensional model (MATHEW) has been developed to provide nondivergent wind fields for use in the ADPIC model and in other studies. MATHEW adjusts interpolated field data subject to the constraints of mass continuity and explicitly introduced topography. This model is also available for other studies such as wind-power site assessments and the determination of topographic influences.

For studies in the stratospheric regime for the Climatic Impact Assessment Program (CIAP) of the Department of Transportation (DOT), models 7, 8, 9, 10, and 11 have been developed. These models resulted from interdivisional effort at LLL.[9, 10]

7. A dispersion and transport model, which consists of single-plume and flight corridor models, has been developed to describe the wake concentration history in the transition region from the stabilized aircraft wake to the global scale. These models are designed to determine the effects on the quasi-equilibrium concentrations characterizing a flight corridor caused by (a) early period concentrated wake kinetics, (b) the spatial and temporal distribution of wake injections (i.e., the injection schedule), and (c) dispersion of individual wake plumes by scale-dependent eddy diffusion and/or shear.[10]

8. The coupled kinetics and transport modeling includes one- and two-dimensional numerical models to simulate, using prescribed mean winds and eddy diffusion coefficients, vertical and latitudinal dispersion and chemical transformation of stratospheric trace gases. These models (described below) include interactive radiation transport but allow no feedback of the trace gases on the transport. These models are intended to compute quasi-equilibrium distributions of trace species resulting from prescribed stratospheric injection schedules.[10]

9. A stratospheric kinetics model simulates the chemical and photochemical kinetics of the stratosphere. The model includes the kinetics of a well-mixed cell, gaseous absorption and concomitant attenuation of the downwelling solar spectrum, and application of advanced mathematical methods. Considerable attention is directed toward the development of a capability to evaluate the following:
   a. sensitivity of reaction mechanisms to deficiencies in our knowledge of the solar constant, reaction rates, quantum yields, reaction ensemble, and reactant concentrations;
   b. the effect of using diurnally and seasonally varying solar flux (as opposed to time-averaging solar flux); and
   c. the feasibility of developing reduced reaction sets for incorporation in more complex models, permitting interaction with other atmospheric processes.[10]

10. Two highly accurate solar radiation models, RAD1 and PHOTO1, have been developed. RAD1 is used for calculations involving the total solar flux, whereas PHOTO1 is limited to the ultraviolet and visible part of the spectrum. In RAD1, the radiative transfer equation for a cloudless, plane-parallel atmosphere is solved using a successive-scattering iterative procedure. The model includes molecular and Mie scattering along with adsorption by aerosol, ozone, water vapor, carbon dioxide, and oxygen. The solar spectrum between 0.285 and 2.5 μm is divided into 83 discrete spectral intervals, and the vertical column is divided into up to 500 layers depending upon the optical thickness of the atmosphere. The direct solar flux and the upward and downward diffuse fluxes for each spectral interval at each level are computed, taking into account all orders of scattering.[11]

    PHOTO1 is designed specifically to compute photodissociation rates. It differs from RAD1 in that a narrower solar spectrum, from 0.187 to 0.73 μm, is divided into 119 spectral intervals. Ozone and molecular oxygen are the dominant absorbers in this spectral region. Careful attention is given to the Schumann-Runge bands of oxygen (0.187 to 0.205 μm). We are in the process of procuring a highly detailed, longwave radiation model to supplement the solar radiation models.

11. A variety of computer routines and programs for interpreting and analyzing raw data collected by satellites is currently being developed. These data consist of measurements of various physical and chemical constituents in the atmosphere. The present effort is being pursued concurrently along two paths. The first path is the development and/or acquisition of computer software for reducing the raw data to a format suitable for numerical analysis. This phase is in an early stage of development, and little can be reported on at this time. The other path involves the development (or acquisition) of software to perform the analysis and evaluation of various types of data.

    A simple technique for a first analysis of the concentration and distribution of these constituents is to produce contour plots of the concentrations both temporally and spatially. This is useful because of the very large amount of data provided by the satellite measurements. To this end we have obtained (1) a corrographic mapping program (CAM), which uses various projections to draw maps of any part or all of the world, and (2) two contour plotting programs. The intent is to overlay the contour plots onto the relevant maps. The corrographic mapping program has been tested and found to be readily adaptable to our purposes. The contour plotting programs have not been adapted to our computers but should be ready to test shortly.

    One of these programs, obtained from the National Center for Atmospheric Research, Boulder, Colorado, requires that the irregularly distributed data, which are inherent to satellite measuring systems, be first interpolated or fitted to a regularly spaced grid before they can be contoured. The other contour plotting program [named CONTOUR and obtained from the National Aeronautics and Space Administration (NASA)] requires the same regularly spaced grid network, but the translation of the data points to a regular grid is performed internally by the program. A decision as to which program will be more useful to our purposes will be made when both have been tested.

All of the above mentioned tools permit the performance of a variety of environmental assessments and constitute a strategic base for launching new projects directed at filling significant technical needs.

PROGRESS ON PROJECTS DURING FY 1974

The Atmospheric and Geophysical Sciences Division program during FY 1974 involved the development and application of the hierarchy of models discussed above for the AEC and a number of other government agencies. The greater part of the AEC work was sponsored by the Division of Biomedical and Environmental Research which funded G-Division primarily for the first two of the research projects discussed below.

REGIONAL ATMOSPHERIC MODELING

The objective of the regional atmospheric modeling project is to develop a suite of validated numerical simulation models to calculate the transport, diffusion, and if appropriate, deposition that can arise from the vented inventories from pollutant sources at a point or in a volume, whether instantaneous or continuous in character. The models developed will include the effects of speed and directional shear in the transient horizontal wind field, time and space variable eddy diffusion coefficients, and space variable surface roughness. The simulation models developed will use computer time economically, and hence will be applicable in solving regional and continental pollution problems rapidly and/or in real-time. It is anticipated that the output of this developed capability would be integrated surface pollutant concentrations giving hourly, monthly, or annual average surface air concentrations and/or depositions which could be converted to pathway drives to estimate individual and population doses from the significant pollutants.

Mass Consistent Wind Field Modeling

MACAW,[6] which is a mass consistent wind field model in two horizontal dimensions and which has been under development for the past two years, objectively determines advective fluxes that are consistent with the kinematic boundary conditions of the earth's surface, the time and space history of a specified inversion layer acting as a lid, and the conservation of mass in two dimensions. It has become evident that the flux of air (and pollutants) through the inversion, the convective ablation of the inversion, and the reformation of the inversion must be treated in calculating the wind field. Furthermore, internal no-flow-through boundaries are required where the topography penetrates through the inversion base, forcing the winds to carry pollutants around these obstructions. Thus we have formulated a three-dimensional version with internal no-flow-through boundaries. A preliminary analysis indicates that an improved adjusted flux field results when it is initially assumed that *all* inversion height change results from the mechanisms mentioned above and the winds are forced around the mountains under low inversion base conditions.

MATHEW, a three-dimensional mass consistent wind field model, was developed this year to provide ADPIC (see below) with time and space varying, nondivergent wind fields over complex terrain. This model, although based on the variational method of objective analysis, is different than the MACAW model. MATHEW adjusts observations of the horizontal wind field interpolated to a horizontal grid and extrapolated in the vertical so that the adjusted wind field satisfies the three-dimensional continuity equation. Topography is explicitly introduced as a variable lower boundary in the model. Initial validation studies were made using wind data from the Nuclear Reactor Test Station (NRTS) at Idaho Falls, Idaho. Further validation studies are planned this year with wind data from the Savannah River Plant.

Atmospheric Transport and Diffusion

ADPIC (Atmospheric Diffusion Particle-in-Cell) is a numerical, three-dimensional, Cartesian, particle-diffusion code capable of calculating the time-dependent distribution of air pollutants under many conditions including strongly disturbed advection wind fields, calm conditions, space-variable surface roughness, wet and dry deposition, radioactive decay, and space- and time-variable diffusion parameters. The method is based on the particle-in-cell technique with the pollutant concentrations represented statistically by Lagrangian marker particles within an Eulerian grid mesh. The chief advantage of using this technique is that the fictitious diffusion, inherent in purely Eulerian schemes for computing transport and diffusion, is eliminated.

ADPIC and its verification against selected, closed Gaussian solutions was completed this year. In addition, ADPIC was applied extensively on the regional scale in the AEC Reactor Safety Study. In a variety of ways, this study used ADPIC to model the transport and diffusion of instantaneous and continuous pollutant releases in the presence of time- and space-varying winds including shear, complex topography, radioactive decay, radioactive plume rise, dry deposition, and atmospheric inversion layers.

Estimating Dose-to-Man

DOSCON was developed this year to estimate individual and population doses from normalized concentration estimates calculated by ADPIC. Output from this computer code includes isopleths of individual lung, gastrointestinal tract, and whole body doses along with the maximum dose for each. For any given population distribution, isopleths of the population doses for the three pathways listed above are computed and the total man-rem dose for whole body exposure is calculated for the entire area of exposure. This code can accept any given source inventory, fraction released, solubility, and current dose conversion constant. Presently we are updating this code to include additional pathways of exposure.

Boundary Layer – Urban Heat Island Simulation

Using the varied means of literature review, invited seminar speakers, and summer program hiring, significant progress was made in the assessment of the state-of-the-art of boundary layer and urban heat island modeling. As a result, we are now approaching the point where we will make our choice as to the "best" K-model and, since we are also considering more advanced models, the "best" turbulence transport model. Although further research is required, the interim conclusion reached during this year is that a time-dependent turbulence transport model is almost within our grasp and definitely worth further effort.

In conjunction with our assessment study, URBMET, a two-dimensional urban heat island model developed by R. Bornstein of the San Jose State University, San Jose, CA, was improved as follows: variable time stepping was used to increase running speed by a factor of eight or so, equations for the transport and diffusion of water vapor were added, and a study of the effects versus the predicted results after several diurnal cycles was begun.

Plume Rise Simulation

During the course of other studies, the need for modeling the dynamics of "small" plumes with "slight buoyancy" became apparent. Therefore, a new model for predicting plume rise was developed, in which the role of normal atmospheric turbulence was dominant in the plume mixing (entrainment) process. This model differs from conventional models, wherein the mixing is caused by edge entrainment (Taylor entrainment), because the plume has sufficient buoyancy to generate its own flow field, thereby relegating atmospheric turbulence to a minor role. It is believed that atmospheric turbulence should play a progressively larger role as the buoyancy forces become arbitrarily small.

This new model was also extended to make a first approximation at combining the effects of edge entrainment and atmospheric turbulence entrainment; further improvements of this combined model are desirable.

ATMOSPHERIC RELEASE ADVISORY CAPABILITY

In FY 1973, the Division of Biological and Environmental Research requested that the results from their atmospheric research program and experience gained in estimating dose-to-man be focused on the real-time prediction of individual and population doses which could be expected from a massive release of radioactive or other toxic materials. It was then proposed that this capability be made available in the form of advisories to AEC sites and facilities in the event of radionuclide releases. A three-phase study was initiated at LLL which provided for concept, prototype, and implementation of an Atmospheric Release Advisory Capability (ARAC).[12,13] The ARAC will, through an improved advisory product and a faster response time, provide a focal point for a progressive improvement in the AEC function of providing advice and assistance, if requested, to responsible local and state authorities as well as to nuclear facility operators in the event of an actual or potential nuclear incident. The concept study is complete and prototyping is in progress.

The fundamental objective of the ARAC service is to provide real-time predictions of the effects of atmospheric releases of hazardous materials as *rapidly* and *accurately* as possible. The technical basis for ARAC includes the present state-of-the-art of related technology (sensing, monitoring, communications, data banking, data quality control), the utilization of the existing or recently developed and validated atmospheric transport-diffusion models, the use of evaluated dose conversion constants for the various modes of exposure, and the availability of an advanced computer center. An ARAC that provides real-time predictive dose estimates, their regional distribution, and designed countermeasures advisories requires inputs not normally available at a nuclear site. Therefore, the ARAC could integrate services, information, techniques, and resources into a comprehensive service available for many sites with reasonable economy. When implemented, the ARAC would support the present AEC role in several important ways. These include, but are not limited to, the following:

- The quality of information and radiological advisories from the AEC would be improved due to the availability of real-time data and regional information.

- The predicted off-site radiological effects would include transient regional transport porcesses.
- Any off-site countermeasures and post-emergency cleanup operations could be changed and improved as actual radiological information is received.
- The ARAC, as previously mentioned, would serve as a focal point for future improvements in the assistance and advisories provided by the AEC.

Prime objectives for this year were continued regional model validation at complex and relevant sites and development of the real-time data communication systems for releases of opportunity at the Savannah River Laboratory (SRL). SRL has access to meteorological measurements from a 312-m TV tower near Augusta, Georgia, and from seven 60-m towers at the Savannah River Plant. L-Division and the Electronic Engineering Department of LLL helped develop the data communication system used to transmit these meteorological data across the continent to LLL. The system is an adjunct to the L-Division analog data processing center. Software has been written for graphical display of the incoming data and for writing data tapes which are used for input to the regional transport models. (See Figs. 1 and 2.)

A meteorology laboratory has been installed at LLL with National Weather Service input data available in the form of FOFAX and NAFAX plus circuits A and C teletype. During a series of exercises with SRL in FY 1974, this facility was utilized to help with the forecasting of large scale synoptic changes in the weather patterns.

Computer codes for the various numerical models used to estimate concentrations of radionuclides were interfaced to run operationally on the CDC 7600's at LLL. Near the end of FY 1974, several real-time exercises were run in conjunction with SRL to test the present prototype of the ARAC service. Helicopter and other mobile concentration sensors were used to assemble measurements of AR^{41} for use in validating the numerical models.

It is our intent that seven AEC nuclear facilities be included in the ARAC service by the end of FY 1977.

Fig. 1. Prototype data acquisition, communication, and display facility for ARAC.

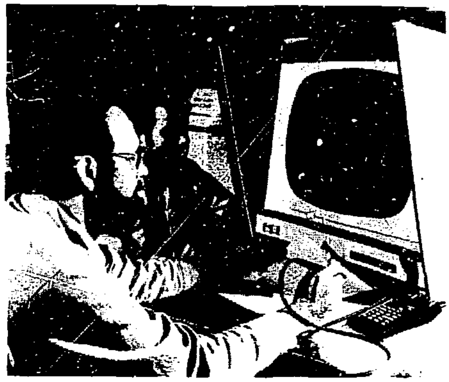

Fig. 2. Real-time graphical display of meteorological data for ARAC.

At that time, the structure of the communication and operational systems would be such that additional AEC or commercial facilities could be added with a minimum amount of effort.

RESUSPENSION OF SURFACE DUST

During this year, G-Division made unique contributions to the Division of Biological and Environmental Research project for understanding the interaction of wind and surface dust. For the first time, dust suspended from the earth's surface by wind was studied on a time scale of importance to turbulent transport, diffusion, and suspension in the atmosphere. Our input to the present study included both experiment and theory. An experiment was designed based on aerosol light scattering instrumentation and wind measurements in cooperation with LLL's Biomedical and Environmental Research Division. It was similar to an earlier 1974 experiment by Porch[14] and was performed in Plains, Texas. The data was analyzed using frequency and power spectral analysis of wind and dust. The detailed results of this experiment are reported by Porch and Shinn[15] and may be summarized as follows:

- Strong correlations of wind speed and dust were obtained over 3-hr periods during a dust storm with data taken every second (correlation coefficient ∿0.9).

- The short term dust flux was found to be related to a very high power of wind speed above threshold (wind speed to the fifth to seventh power) during the height of dust storm activity.

- For the first time, the autospectral density of aerosol was compared to simultaneous wind autospectra which showed the interaction of transport and suspension of dust by the turbulent energy of wind.

RASMUSSEN STUDY: TRANSPORT PHASE

For the transport phase of the AEC Reactor Safety Study,[16] we performed a series of calculations of the transport, diffusion, and dry or wet deposition of a spectrum of accident-vented isotopic inventories (provided by the Rasmussen Safety Analysis Task Force) for a variety of sites, from the meteorologically simple to the more complex.

A comparison between experimental concentration measurements of an ^{131}I release at the NRTS at Idaho Falls and estimates based on our transport and diffusion codes showed that the advanced models (MACAW and ADPIC) more accurately predict the concentration measurements at distances of 50-80 km than the Gaussian diffusion model. The latter estimates the peak concentration with the same accuracy as the advanced models but cannot duplicate the bifurcated plume measured at these distances. Off axis estimates of concentrations based on the Gaussian plume model are orders of magnitude less than those actually measured. The advanced models predicted the correct crosswind pattern although some sampling points were underestimated.

Measurements of the Brookhaven ^{41}Ar plume out to 250 nautical mi were used to test the gamma cloudshine module of the ADPIC transport and diffusion code and to test its transport and diffusion properties. The results for flight paths through crosswind cross-sections of the plume at 125, 200, and 250 nautical mi showed only a 30% discrepancy between the measured and the calculated gamma flux.

We then calculated the individual and population doses for postulated Class 9 nuclear power reactor accidents at Dresden, D.C. Cook, and Turkey Point nuclear reactor sites. We devised a methodology to calculate the transport, diffusion, and deposition which could result from such a release. Much of the input for this study, such as initial fission product inventory, fraction released, and climatology for each site, was provided by the Reactor Safety Study Panel.

ADPIC parameter sensitivity studies showed that surface air concentration and ground deposition calculations were least sensitive, but not insensitive, to vertical directional wind shear. Of greater importance was the particulate and iodine deposition velocity which can effect the air concentrations by an order of magnitude over a zero deposition velocity specification. The most critical parameter turned out to be the plume rise specificaiton. This was especially true for the low windspeed, F stability case. The difference in calculated air concentrations out to 20 km can be up to two orders of magnitude between the two plume rise models we used. However, for the other F stability and the D stability cases, this difference is not as significant.

CLIMATIC IMPACT ASSESSMENT PROGRAM

The Department of Transportation through its Climatic Impact Assessment Program (CIAP), is seeking to determine the potential effects on global climate that might be caused by operation of large numbers of aircraft in the stratosphere. The results of these studies are expected to be published as a series of monographs in 1974. As a contributor to that program, LLL has undertaken a number of studies emphasizing numerical model development and application. This large effort in modeling atmospheric processes has been undertaken jointly by the Atmospheric and Geophysical Sciences Division (G), the Theoretical Physics Division (T), and the Chemistry and Computation Departments.

Understanding any problem as complex as the response of the atmosphere to prescribed perturbations requires a thorough mix of observational and theoretical studies, blended through the medium of numerical models. Experience in the numerical modeling of applied research problems has enabled us to formulate a hierarchy of models, each of which not only focuses on discrete subproblems that deserve individual study but also contributes to the analysis and modeling of the larger, overall problem.

Five distinct modeling efforts are underway. Three of these are based on the different scales of atmospheric motion. The other two address stratospheric kinetics and radiation transport. The five different modeling efforts, some of which involve more than one model, are:

- Dispersion and transport model.
- Global kinetics and transport model.
- Zonal Atmospheric Model (ZAM2).
- Stratospheric kinetics model.
- Radiation transport model.

In particular, these models treat the diffusion and transport of aircraft exhaust emissions and the photochemical reactions of these pollutants with ozone and other components of the ambient atmosphere, focusing on the mechanisms and results of possible modifications in the composition of the stratosphere. From these calculations, induced changes in the global climate and ultraviolet radiation at the earth's surface can be investigated.

While our first year efforts emphasized model development,[9] the interdivisional attention during FY 1974 has been primarily directed toward model validation and application.[10] The scope of these efforts has been very broad, ranging from the study of individual aircraft wakes to the global scale. For example, we have found that the effect of pollutants from a single aircraft does indeed create an ozone hole, but that as the pollutants spread out the natural ozone tends to fill the hole which reduces the amount of destruction. We have assessed the effect on the global ozone of the atmospheric nuclear test series of the early 1960's and the effect of more recent individual explosions on the local ozone levels. We have studied the effect of atmospheric scattering on the photodissociation rates used in kinetics computations. We have undertaken an intercomparison of certain characteristics of kinetics models used by various investigators in order to understand why these models get different results while apparently simulating the same problem. We have looked at the effect on the global radiation budget of aerosol and ozone perturbations. Along with these many studies, we have participated in writing the CIAP monographs being prepared to assimilate all relevant research.

Late 1974 is the target date for completing the CIAP project. In this study, our models have been useful tools for developing the required understanding of the atmosphere so that a proper evaluation of the climatic impact of stratospheric aerospace operations can be carried out.

SAN FRANCISCO BAY AREA AIR POLLUTION MODEL

With funding from the Research Applied to National Needs (RANN) Program of the National Science Foundation (NSF), the Laboratory is participating in a joint effort with the Bay Area Air Pollution Control District (BAAPCD) and the NASA-Ames Research Center (ARC) to develop a validated regional air quality model which may be applied in assessing various alternatives in regional land use and in planning control abatement strategies.[6] The primary responsibilities of the BAAPCD are to provide a source emission inventory, to provide guidance for model development by defining the needs for model application, and to direct the observational program being undertaken to acquire data for model validation. The major responsibility of ARC in the joint study is to provide an instrumented aircraft to acquire data for model validation, with an additional minor role in developing a photochemical reaction set. In addition to overall responsibility for the study, LLL is charged with developing the suite of models that will be capable of converting information on source strengths and meteorology to measures of air quality. Thus, we have developed a substantial capability for building a meteorological data base which includes ground station and aircraft data. The rather sparse meteorological data is objectively analyzed using MACAW in order to provide self-consistent detailed fields of wind speed, wind direction, and inversion height over the region. Additional models extract the appropriate topographic and source emission data from the large sets of data provided to us. The source, topographical, and meteorological data are input to the Livermore Regional Air Quality (LIRAQ) model which then develops air quality fields that can be compared against observed air quality data in validation studies. The present LIRAQ model is significantly improved over an earlier LLL model, and further development is underway which will provide[17] for photochemical evolution of air pollutants. In addition, data collection efforts have been processed into a Master Control data base (a LLL computer program) which permits extraction of data sets of primary pollutants using nested searching techniques and macro-expansions.

Joint studies by LLL and the BAAPCD are presently underway to develop "scenarios" of the typical situations to which the BAAPCD wants to apply the LIRAQ model. With completion of these studies late in calendar year 1974, the suite of models will be made available to the BAAPCD to use in policy formulation and decision-making.

CLIMATIC EFFECT OF NUCLEAR EXPLOSIONS

High-yield atmospheric nuclear explosions during the test series in the early 1960's are believed to have injected nitrogen oxides into the stratosphere. In the course of our CIAP studies, data concerning these effects have been used to assist in validation of stratospheric transport kinetics models. Because of the potential climatic effects which might result from nitrogen oxide injection, it became evident that further studies on the potential climatic impact of atmospheric nuclear explosions were needed.

During FY 1974, very preliminary calculations were performed which indicated that if very large numbers of megaton-range atmospheric nuclear explosions were to take place, potentially significant reduction of the atmospheric ozone layer for several years would be likely, resulting in increased solar ultraviolet radiation reaching the surface and possibly some consequent transient climatic readjustment. The Laboratory effort during FY 1975 will include further research into the amounts of various materials injected into the atmosphere and into the chemical, radiative, and climatic response to potential injections.

PRECIPITATION SCAVENGING

Over the past three years there has been a growing awareness in the Defense community and AEC circles of the potential collateral damage hazard associated with tactical nuclear weapons and their possible use in limited wars.[18,19] It has become increasingly apparent that reliable estimates are needed of the expected ranges of radiation doses from low yield devices in various meteorological, demographic, and military settings. Such information is of vital importance to military decision makers in assessing the significance of collateral damage and in properly considering alternatives. Our effort in precipitation scavenging (rainout) has been primarily in two categories: (a) assessment and (b) focused, applied research aimed at developing suitable, validated assessment models or submodels. For instance, we have employed a parameterized microphysics scavenging submodel incorporated into a one-dimensional cloud model which was then used to simulate the removal of atmospheric aerosol particles in regions with high precipitation rates.

Technical uncertainties (e.g., particle size distribution and specific activity within the debris cloud and renewal rates) have historically led to various projections regarding the seriousness of the rainout problem and the probability of associated population exposures. We are performing and will continue to perform field and laboratory measurements to reduce some of these uncertainties and to understand some of the fundamental microphysical questions.[20] It is our judgement that our current rainout assessment results indicate that rainout radiation fields are a significant contributor to collateral damage. We believe that the role of experimental efforts and focused applied research is to reduce the identified uncertainties and hence contribute to the development and assessment results of improved quality and confidence.

SAN BERNARDINO FOREST ECOSYSTEM STUDY

Under an interagency agreement between the Environmental Protection Agency (EPA) and the AEC, LLL is developing a data management system which will process field data for an oxidant impact study being conducted by staff of the University of California (Berkeley and Riverside) on the San Bernardino National Forest. The data management system is divided into two sections. The first section is a data capture system in which field data is entered into a computer system in an efficient manner with minimal loss. The data capture system is composed of eight major computer routines – one for each of the above components. The second section is a data banking in which Master Control[17] is used to create and manipulate data files into operational records which can be analyzed using available statistical and graphical techniques. Such analyzed data can be used to study the effects of oxidants on various components of a mixed conifer forest. Such data could provide input information into an ecosystem model.

We have participated in the development of a modeling scheme which can be applied to biological systems which are both complex and highly structured. The technique is essentially a Monte Carlo process which is designed to effectively exploit the structure inherent in a population by making use of appropriate mathematical formalism and computer algorithms. This technique could be effectively applied to the arthropod effort of the study if appropriate data is collected. If the technique proves successful, it could be an extremely useful research tool in understanding the structure and complexity imbedded in population ecology. At present, such a tool does not exist.

OTHER PROJECTS

G-Division is often asked to provide general support to the Laboratory for studies that require atmospheric and geophysical science input. For instance, during FY 1974 we made revisions to the FY 1973 safety analysis reports for the Livermore Pool Type Reactor and for the annex to the Metallurgical Chemistry building. In addition, the meteorology chapter of a safety analysis report for the LLL Super Kukla reactor (at the Nevada

Test Site) was substantially completed. Estimates were also made of off-site tritium doses from operation of a proposed Fusion Engineering Research Facility.

Support was also provided to the Plowshare program. We made diffusion and deposition estimates for nuclear construction of a Kra Canal and for a Qattar Depression project. A staff member was sent to the Rio Blanco, Colorado, site during the first flaring of the nuclear-simulated gas well. Meteorological observations and forecasts for the surface boundary layer were prepared and updated daily to ensure that the tritium-bearing flaring plume would not pass over populated areas, particularly during precipitations. Support was also provided to the Plowshare program in preparing an AEC statement on the proper conduct of peaceful nuclear explosives projects. Finally, a paper[21] was co-authored with a Plowshare staff member for publication in the *Proceedings of the Noble Gas Symposium in Las Vegas, September 1973.*

The AEC Nevada Operations Office requested G-Division's participation in preparing an environmental statement for the National Nuclear Test Readiness Program. We provided fallout and long-range deposition estimates for a number of nuclides, assuming a hypothetical test series. Participating oceanographers calculated the resultant individual and population doses via the seafood-man pathway; G-Division calculated similar doses for cloud passage over the United States.

STAFFING AND FUNDS

Staffing within the G-Program at the end of FY 1974 was 38 persons including 3 secretaries. Of this total, 27 persons were assigned to G-Division; the remainder were assigned to other scientific and supporting organizations.

New senior staff arrivals during FY 1974 were:

James F. Barbieri, M.S., formerly LLL Theoretical Physics Division; numerical hydrodynamics and cosmology.

John A. Korver, M.S., formerly technical staff, Systems, Science and Software, Inc.; geophysics.

Robert L. Lee, Ph.D., formerly assistant professor, Mechanical Engineering Department, University of Miami, Coral Gables, Florida; geophysical fluid dynamics and radiative transfer.

James E. Lovill, Ph.D., formerly technical staff, U.S. Air Force Global Weather Central, Offutt AFB, Nebraska; meteorology and satellite data analysis.

Thomas J. Sullivan, M.S., formerly Chief, Mission Applications Section, U.S. Air Force Global Weather Central, Offutt AFB, Nebraska; numerical objective and satellite data analysis.

Donald J. Wuebbles, M.S., formerly technical staff, Environmental Research Laboratories, NOAA, Boulder, Colorado; interaction between atmospheric dynamics and chemistry.

Total funds expended during FY 1974 were $1,430,000 including $5,000 for capital equipment. Of the total funding, the AEC provided 36%; the DOT about 39%; the Department of Defense about 13%; the NSF, 10%; and the EPA, 2%

Computer time used included 298 hr on the CDC 7600 and 24 hr on the CDC 6600.

CONCLUSIONS AND PROJECTS FOR FY 1975

In this report we have summarized the highlights of the Atmospheric and Geophysical Sciences Division's research program for FY 1974. We again emphasize that the program is an interdivisional effort with support from a number of scientific and engineering organizations. In retrospect, we are satisfied with the progress on the component projects of the program during the past year. More importantly, we have assembled the assets required for a continuing and expanding program in this field. An outstanding team of scientists and supporting personnel have proven their abilities, the analytical tools are available and are being improved, and the capability to attack and resolve specific system problems has been demonstrated.

In FY 1975, we anticipate that the G-Division research program will find its framework and baseline in past division projects. For instance, we foresee an orderly and systematic development of the Atmospheric Release Advisory Capability and its extension to other key sites selected by the AEC. This general effort will be supported by regional numerical simulation modeling developments. These developments include mass-consistent modeling in two and three dimensions in the presence of complex terrain; the modeling of buoyant plumes containing momentum, heat, or internal heating from decay products or chemical transformations; new modeling approaches to three-dimensional hydrodynamic flow over complex structures or terrain; and implementation of two- and three-dimensional urban heat island models with inclusion of simple turbulence models. Also, as resources permit, modern fast-response nephelometers and other instruments will be used to study the process of resuspension of plutonium and other toxic materials from various surfaces.

Research and assessment activities bearing on the potential effect of a variety of man's activities on the ozone will continue in the coming year. These activities will be directed toward assessing the global impact of stratospheric and aerospace operations, and also toward determining the climatic impact of very large numbers of high-yield nuclear explosions and of chlorofluoromethanes released as spray can propellents. We will try to determine the fate of chlorofluoromethanes in the atmosphere. By virtue of new remote assessment capabilities from satellites, new perspectives may be possible on world resources such as food and fibers. These issues will be strongly reflected in our assessment activities.

The regional numerical simulation capability of photochemical pollutants (which we expect to complete about January 1, 1975) appears to be a strong candidate for application to other air quality basins in the U.S. where the techniques may be applicable with nominal changes in input or photochemical or emission inventory information. We also see that the techniques thus far developed and validated may provide a basic capability for a realistic attack on regional sulfur budgets, including the various chemical or radiative modes of transformation of the SO_2 during its residence in a regional area.

In general, we feel that the time has arrived to focus the capabilities enumerated in this report into an integrated assessment mode and then to apply it, in a system sense, to assist this nation in making critical decisions concerning energy, environmental, and agricultural resources.

References

1. M. C. MacCracken, *Tests of Ice Age Theories Using a Zonal Atmospheric Model,* Lawrence Livermore Laboratory Rept. UCRL-72803 Preprint (1970).
2. M. C. MacCracken, "Zonal Atmospheric Model ZAM2," in *Proc. Second Conference on the Climatic Impact Assessment Program, 14-17 November 1972,* DOT-TSC-OST-73-4 (U.S. Dept. of Transportation, Washington, D.C., 1973).
3. T. V. Crawford, *A Computer Program for Calculating the Atmospheric Dispersion of Large Clouds,* Lawrence Livermore Laboratory Rept. UCRL-50179 (1966).
4. J. B. Knox, T. V. Crawford, K. R. Peterson, and W. K. Crandall, *Comparison of U. S. and U.S.S.R. Methods of Calculating the Transport Diffusion and Deposition of Radioactivity,* Lawrence Livermore Laboratory Rept. UCRL-51054 (1971).
5. M. C. MacCracken, T. V. Crawford, K. R. Peterson, and J. B. Knox, *Initial Application of a Multi-Box Air Pollution Model to the San Francisco Bay Area,* Lawrence Livermore Laboratory Rept. UCRL-73348 Preprint (1972). Published in *Proc. Joint Automatic Control Conf., Stanford, Ca., 1972.*
6. *Development of an Air Pollution Model for the San Francisco Bay Area, Second Semiannual Report to the NSF,* Lawrence Livermore Laboratory Rept. UCRL-51537 (1974).
7. M. H. Dickerson, *Summary of Research Related to Mass Consistent Wind Field Analysis for the San Francisco Bay Area,* Lawrence Livermore Laboratory Rept. UCRL-74265 Preprint (1972).
8. R. Lange, *ADPIC – A Three-Dimensional Computer Code for the Study of Pollutant Dispersal and Deposition Under Complex Conditions,* Lawrence Livermore Laboratory Rept. UCRL-51462 (1973).
9. *First Annual Report, CIAP Program,* Lawrence Livermore Laboratory Rept. UCRL-51336 (1973).
10. *Second Annual Report, DOT-CIAP Program,* Lawrence Livermore Laboratory Rept. UCRL-51336-74 (1974).
11. F. M. Luther, *Solar Radiation Model RAD1,* Lawrence Livermore Laboratory Rept. UCID-16572 (1974).
12. M. H. Dickerson, J. B. Knox, J. J. Cohen, and R. C. Orphan, *Concept for and Atmospheric Release Advisory Capability,* Lawrence Livermore Laboratory Rept. UCRL-51656 (1974).
13. J. B. Knox and T. V. Crawford, *Atmospheric Release Advisory Capability,* Lawrence Livermore Laboratory Rept. UCRL-75644 Preprint, Rev. 1 (1974).
14. W. M. Porch, *Atmospheric Environ.* 8, 897 (1974).
15. W. M. Porch and J. H. Shinn, *Fast-Response Light Scattering Measurements of the Characteristics of Wind Suspended Aerosols,* Lawrence Livermore Laboratory Rept. UCRL-76014 Preprint (1974).
16. *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants,* Atomic Energy Commission, Washington, D.C., Draft Rept. WASH-1400 (1974).
17. V. E. Hampel and J. A. Wade, *Utilization of Scientific Data Bases at LLL Using the Master Control Computer Program,*
18. J. B. Knox, T. V. Crawford, and W. K. Crandall, *Potential Exposures from Low-Yield Free Air Bursts,* Lawrence Livermore Laboratory Rept. UCRL-51164 (1972).
19. W. K. Crandall, C. R. Molenkamp, A. L. Williams, M. M. Fulk, R. Lange, and J. B. Knox, *An Investigation of Scavenging of Radioactivity from Nuclear Debris Clouds: Research in Progress,* Lawrence Livermore Laboratory Rept. UCRL-51328 (1973).
20. J. B. Knox and A. L. Williams, *Rainout Studies at Lawrence Livermore Laboratory,* Lawrence Livermore Laboratory Rept. UCRL-51530 (1974).
21. J. J. Cohen and K.R. Peterson, *Considerations in Siting Long-Term Radioactive Noble Gas Storage Facilities,* Lawrence Livermore Laboratory Rept. UCRL-75243 Preprint (1973). Published in *Proc. Noble Gas Symposium, Las Vegas, Nevada, September 24-28, 1973.*

Annotated Bibliography of FY 1974 G-Division Publications

Listed in chronological order are publications produced by G-Division during FY 1974.

Program Report – FY 1974, Atmospheric Sciences Group, Physics Department, Lawrence Livermore Laboratory, Lawrence Livermore Laboratory Rept. UCRL-51444 (August 1973).

A description of unique G-group modeling capabilities including a suite of numerical atmospheric models which operate on a wide spectrum of scales for a variety of source and pollutant types. The relationship between these capabilities and existing national needs is discussed.

R. Lange, *A Three-Dimensional Computer Code for the Study of Pollutant Dispersal and Deposition under Complex Conditions,* Lawrence Livermore Laboratory Rept. UCRL-51462 (October 1973)

A three-dimensional particle diffusion code developed to calculate the evolution of a puff or plume in a transient atmospheric boundary layer is presented. The model is based on the particle-in-cell (PIC) concept with the hydrodynamical aspects of the conventional PIC replaced by a given mass consistent wind field. The model considers the effects of advection, diffusion, decay, and time varying meteorological and topographical conditions.

R. J. Gelinas and J. J. Walton, *Dynamic-Kinetic Evolution of a Single Plume of Interacting Species,* Lawrence Livermore Laboratory Rept. UCRL-75720 Preprint (October 1973). Submitted to *J. Atmos. Sci.*

This report describes the evolution of an SST injected plume from the end of the aircraft-induced turbulence regime out to global scales and considers both the effects of dispersion and chemical transformation.

J. B. Knox, M. H. Dickerson, P. M. Gresho, R. Lange, C. A. Sherman, K. R. Peterson, E. V. Jankus, and P. H. Gudiksen, *Reactor Safety Study: Part I, Methods of Calculating Atmospheric Transport* (October 1973). Internal LLL report prepared for the AEC Reactor Safety Study.

Describes and helps verify a suite of three-dimensional models used to calculate long-range surface, air, and ground concentrations which can result from a release of radioactive (or conventional) pollutant to the atmosphere. Topics covered include considerations of plume rise resulting from initial buoyancy and internal heating due to beta decay, meteorological measurements and analysis, site topography, transport, diffusion and the prescription of the diffusion parameters. Comparisons are made with experimental concentration measurements taken at the NRTS, Idaho Falls, and at Brookhaven National Laboratory, Massachusetts.

W. M. Porch, *Recent Studies of the Suspension of Desert Dust and Resuspension of Toxic Aerosol Due to Wind,* Lawrence Livermore Laboratory Rept. UCRL-75194 Preprint (December 1973).

Data collected on the resuspension of desert dust using fast response aerosol detection instrumentation is analyzed. Preliminary results indicate that resuspension can occur in association with comparatively low average wind velocities with a diurnal pattern.

J. B. Knox, M. H. Dickerson, P. M. Gresho, R. Lange, and C. A. Sherman, *Reactor Safety Study: Part II, Dose Calculations for Three Nuclear Sites (Dresden, D.C. Cook, Turkey Point* (December 1973). Internal LLL report prepared for the AEC Reactor Safety Study.

This study uses the methodology described in Part I to calculate the individual and population dose for a postulated Class 9 nuclear power reactor accident at three topographically simple sites, each under two meteorological conditions.

J. B. Knox and R. Lange, "Surface Air Pollutant Concentration Frequency Distributions: Implications for Urban Modeling," *JAPCA*, 24(1), 48 (January 1974).

A comparison is made between observed surface air pollutant concentration frequency distributions and those produced by simple modeling concepts for urban area sources and continuous point sources. Passive pollutants emitted from urban area sources are found to produce approximately lognormal frequency distributions which closely parallel the reciprocal of windspeed. It is shown that the constant relating these distributions can be found either experimentally or with a numerical simulation model.

J. J. Walton, *Dispersion of SST Exhaust Plumes in the Stratosphere,* Lawrence Livermore Laboratory Rept. UCRL-74886 Preprint (January 1974). This paper is included in the *Proc. of IAMAP/AIPSO First Special Assembly, Melbourne, Australia, January 1974.*

This report describes sensitivity studies undertaken concerning representation of meteorological behavior of the stratosphere and the resulting effect on the ozone destruction rate for SST injected plumes.

M. C. MacCracken and F. M. Luther, *Climate Studies Using a Zonal Atmospheric Model*, Lawrence Livermore Laboratory Rept. UCRL-74887 Preprint (January 1974). This paper is included in the *Proc. of IAMAP/IAPSO First Special Assembly, Melbourne, Australia, January 1974.*

This report describes the physical basis and structure of the zonal atmospheric model which has been developed to simulate the global climate. An extensive validation sequence is described which is planned in conjunction with studies of the potential climatic impact of aerospace utilization of the stratosphere.

F. M. Luther and M. C. MacCracken, *Initial Validation Studies for ZAM2 Radiation and Large Scale Eddy Transport Mechanisms*, Lawrence Livermore Laboratory Rept. UCRL-75495 Preprint (1974). This paper is included in *Proc. Third Conf. on CIAP, Cambridge, Mass., February 1974.*

This report describes the structure of the atmospheric radiation transport models used in our climate studies and the validation of this model against more detailed models, one of which is under development here at LLL (solar radiation). Representation of the nonzonal eddy transport in the atmosphere is also described.

H. W. Ellsaesser, *Water Budget of the Stratosphere*, Lawrence Livermore Laboratory Rept. UCRL-75162 Preprint (February 1974). Submitted to *J.G.R.*

In addition to numerical simulation models, balances of fluxes of various quantities provide a means of understanding atmospheric behavior. This report is a review and assessment of the water vapor balance of the stratosphere and is intended to serve as a guide to observation strategies and a validation for models.

Development of an Air Pollution Model for the San Francisco Bay Area, Second Semi-Annual Report to the NSF, Lawrence Livermore Laboratory Rept. UCRL-51537 (March 1974).

The results of the first year of effort to develop the multi-box (now called LIRAQ) model are presented and future plans are described. The development includes a running version of the transport code, a reasonably detailed version of the regional source inventory for both mobile and stationary sources, a running version of the mass consistent wind field submodel, a description of the advanced data retrieval system utilized for meteorological and photochemical kinetic data, and a discussion of eventual model applications including the development of the "climatological" model and a possible application scenario.

P. M. Gresho, *Comments on "Periodic Solutions of the Sets of Equations Governing the Nonadiabatic Convection of Dry Isolated Thermals,"* Lawrence Livermore Laboratory Rept. UCRL-75398 Preprint (January 1974).

A physical limitation of the modeling of plume dynamics is pointed out; that is, a plume or thermal which grows while rising via "Taylor entrainment" must also grow if it finds itself in a sinking situation. Additionally, a useful and simple method of mathematical characterization of thermals is presented and applied.

J. P. Knox and A. L. Williams, *Rainout Studies at Lawrence Livermore Laboratory*, Lawrence Livermore Laboratory Rept. UCRL-51530 (February 1974).

The study of rainout has received additional impetus from recent investigations of the impact of collateral damage upon tactical nuclear operations. Additional research is going forward at LLL to provide an improved technical basis for the assessment of rainout. The project is designed to develop improved understanding of the basic physical interactions that control the processes and to assess more rigorously the potential hazards to man. Aspects of the work described in this report include a microphysical description of precipitation scavenging of the nuclear debris aerosol, progress in the numerical modeling of natural cloud systems and their interactions with nuclear debris aerosols, and investigations of possible means of controlling the rainout-removal process. This is an interim report; it is expected that continuing research over the next six months will permit a more precise basis for analysis of the phenomenon.

J. E. Lovill, *A Comparison of the Southern and Northern Hemisphere General Circulation Characteristics as Determined by Satellite Ozone Data*, Lawrence Livermore Laboratory Rept. UCRL-75556 Preprint (March 1974).

Satellite total ozone data have been analyzed for the Southern Hemisphere (autumn and winter) and the Northern Hemisphere (spring and summer). A strong correlation was found between global meridional gradients of total ozone and the wind velocity in baroclinic zones.

The lowest mean ozone value for either hemisphere was at 6°S and the average global value of total ozone for the period was 303.3 m·atm·cm.

Ozone isolines revealed a moderately strong jet stream in the South Pacific Ocean (35°S). The most rapid meridional change of ozone was over Japan. A relatively tight ozone gradient was also seen in the Atlantic Ocean between 40°N and 50°N. This region corresponds to the high density aircraft flight corridor between the eastern United States and the European region (e.g., New York to London or Paris). It is significant that analysis has now shown that this is a region of rapid changes in ozone as well as a depository for stratospheric eff uents from current subsonic jets which operate occasionally in the lower stratosphere and future SST aircraft which will be operating at higher altitudes.

R. I. Pollack, *Optimization of Air Pollution Control Strategies,* Lawrence Livermore Laboratory Rept. UCRL-75501 Preprint (March 1974).

The development of methods designed to determine optimal air quality control strategies using regional air pollution dispersion models that relate emission levels to ambient air concentrations is reviewed. Some of the strengths and weaknesses of several approaches are discussed with particular attention given to the applicability of each in a region where photochemical smog is a significant problem. An application of special interest is presented. The problems and pitfalls facing future efforts are outlined.

W. M. Porch, D. S. Ensor, and R. J. Charlson, *Visibility of Distant Mountains as a Measure of Background Aerosol Pollution,* Lawrence Livermore Laboratory Rept. UCRL-75640 Preprint, Rev. 1 (April 1974).

A relationship is developed between the visibility of distant mountains seen from an aircraft and a level of background aerosol pollution for a model atmosphere. It is found that the distance at which Mount Rainier can be seen on "clean-air" days, which are typical of background aerosol levels, is consistent with the level of aerosol light-scattering measurements in other background situations.

J. B. Knox and T. V. Crawford, *Atmospheric Release Advisory Capability: Research and Progress,* Lawrence Livermore Laboratory Rept. UCRL-75644 Preprint Rev. 2 (May 1974).

This paper briefly summarizes the Atmospheric Release Advisory Capability (ARAC) concept and the present status in regard to the building of the prototype system and initial test of this system in a joint effort between LLL and the Savannah River Laboratory. This capability would, when developed and verified, be made available in the form of advisories to AEC sites and facilities in the event of radionuclide releases. Cooperative efforts between LLL and the Savannah River Laboratory in the southeastern United States are in progress to test the feasibility of applying the ARAC concept to other parts of the U.S.

J. Dave, *A Direct Solution to the Spherical Harmonics Approximation to the Transfer Equation for a Plane-Parallel, Non-Homogeneous Atmosphere,* Lawrence Livermore Laboratory Rept. UCRL-51581 (April 1974).

This report outlines in detail a method for obtaining a direct solution of the spherical harmonic approximation to the equation of radiative transfer through a plane-parallel, non-homogeneous atmosphere containing arbitrary height distributions of abosrbing gases, aerosol particles, and water-drop clouds.

F. M. Luther, *Relative Influence of Stratospheric Aerosol on Solar and Longwave Radiative Fluxes for a Tropical Atmosphere,* Lawrence Livermore Laboratory Rept. UCRL-75760 Preprint (June 1974).

The solar and longwave radiative effects of a stratospheric aerosol layer between 18 and 22 km are compared for a tropical atmosphere. The changes in the daily mean solar and longwave radiative fluxes are computed above and below the aerosol layer for two particle size distributions as a function of the albedo of the earth's surface. The aerosol is assumed to be a water solution of sulfuric acid with a concentration of 75% H_2SO_4 by weight. The changes in the solar and longwave fluxes above the aerosol layer are found to be comparable in magnitude. In the troposphere, the cooling caused by a reduction in the incoming solar radiation is several times greater than the warming caused by an increase in the downwelling longwave radiation; the difference decreases with increasing surface albedo. The solar and longwave effects both tend to warm the aerosol layer, the solar effect being 2 to 4 times greater than the longwave effect.

G. J. Strensland, *Further Numerical Model Studies of the Washout of Hygroscopic Particles in the Atmosphere,* Lawrence Livermore Laboratory Rept. UCRL-51614 (July 1974).

Numerical and analytical methods are used to study rainout and washout of hygroscopic material in the atmosphere. The variation in concentration of hygroscopic material in rain water was investigated as a function of raindrop size class, changing radius of released particles due to drop evaporation, and time from initiation of rainfall.

Recent Publications by Supporting Scientists

Listed here are some related publications produced since 1972 by LLL supporting scientists.

Chang, J. S., "On Stiffness in Chemical Kinetic Transport Calculations," presented at the *Conf. on the Numerical Solution of Ordinary Differential Equations, Austin, Texas, 1972.*

Chang, J. S., "Comments on the Possible Effect of NO_x Injection in the Stratosphere Due to Atmospheric Nuclear Weapons Tests," in *Proc. of Second Conference on CIAP* (Cambridge, Mass., 1972).

Chang, J. S., and W. H. Duewer, *On the Possible Effect of NO_x Injection in the Stratosphere Due to Past Atmospheric Nuclear Weapons Tests,* Lawrence Livermore Laboratory Rept. UCRL-74480 Preprint (1973).

Chang, J. S., A. C. Hindmarsh, and N. K. Madsen, *Simulation of Chemical Kinetics Transport in the Stratosphere,* Lawrence Livermore Laboratory Rept. UCRL-74823 (1973).

Chang, J. S., and N. K Madsen, *LLL Global Transport and Kinetic Models,* Lawrence Livermore Laboratory Rept. UCRL-75062 Preprint (1973).

Duewer, W. H., and R. J. Gelinas, *LLL Atmospheric Data Library, Edition 4,* Lawrence Livermore Laboratory Rept. UCID-16206 (1973).

Duewer, W. H., and R. J. Gelinas, *User's Guide to LLL Atmospheric Data Library Ordered by Reaction Number, Edition 4,* Lawrence Livermore Laboratory Rept. UCID-16208 (1973).

Gelinas, R. J., "Stiff Systems of Kinetic Equations – A Practitioner's View," *J. Comp. Phys.* 9(2), 222 (1972).

Gelinas, R. J., "Review of Chemical Dynamics from the Diffusive Transport Scale to the Global Scale," in Dept. of Transportation Rept. DOT-TST-90-2, R. Greenstone and R. L. Underwood, Eds. (National Technical Information Service, Springfield, Va., 1972).

Gelinas, R. J., *Radiative Transfer Considerations for Kinetic Modeling and Sensitivity Studies,* Lawrence Livermore Laboratory Rept. UCRL-74504 Preprint (1973).

Gelinas, R. J., R. H. Kummler, and H. B. Levine, "Numerical Analysis," in Dept. of Transportation Rept. DOT-TST-90-1, R. L. Underwood, Ed. (National Technical Information Service, Springfield, Va., 1972).

Gelinas, R. J., *Diurnal Kinetic Modeling,* Lawrence Livermore Laboratory Rept. UCRL-75373 Preprint (1974).

Gelinas, R. J., and J. J. Walton, *Dynamic-Kinetic Evolution of a Single Plume of Interacting Species,* Lawrence Livermore Laboratory Rept. UCRL-75170 Preprint (1973).

Hindmarsh, A. C., *GEAR: Ordinary Differential Equation System Solver,* Lawrence Livermore Laboratory Rept. UCID-30001, Rev. 1 (1972).

Hindmarsh, A. C., "The Control of Errors in the GEAR Package of Ordinary Differential Equations," in *Construction of Mathematical Software,* F. N. Fritsch, Ed., Lawrence Livermore Laboratory Rept. UCID-30050, Part 3 (1972).

Hindmarsh, A. C., *Linear Multistep Methods for Ordinary Differential Equations: Method Formulation, Stability, and the Methods of Norsieck and Gear,* Lawrence Livermore Laboratory Rept. UCRL-51186 (1972).

Madsen, N. K., J. S. Chang, and J. J. Walton, *Scale Dependent Dispersion with Kinetics in the SST Exhaust Plume,* Lawrence Livermore Laboratory Rept. UCRL-74495 Preprint (1973).