BNL 30816
Informal Report

ATMOSPHERIC SCIENCES DIVISION ANNUAL REPORT FOR FISCAL YEAR 1981

Gilbert S. Raynor, Editor

December 1981

DEPARTMENT OF ENERGY AND ENVIRONMENT

BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK 11973

DISCLAIMER

BNL--30816

DE82 016208

BNL 30816
Informal Report

ATMOSPHERIC SCIENCES DIVISION ANNUAL REPORT FOR FISCAL YEAR 1981

Paul Michael, Division Head
Gilbert S. Raynor, Associate Division Head

Gilbert S. Raynor
Editor

December 1981

ATMOSPHERIC SCIENCES DIVISION
DEPARTMENT OF ENERGY AND ENVIRONMENT
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

UNDER CONTRACT NO. DE-AC02-76CH00016 WITH THE
UNITED STATES DEPARTMENT OF ENERGY

DISCLAIMER

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes:
Printed Copy: A07; Microfiche Copy: A01

ABSTRACT

The research activities of the Atmospheric Sciences Division of the Department of Energy and Environment for FY 1981 are presented. Facilities and major items of equipment are described. Research programs are summarized in three categories, modeling, field and laboratory experiments and data management and analysis. Each program is also described individually with title, principal investigator, sponsor and funding levels for FY 1981 and FY 1982. Future plans are summarized. Publications for FY 1981 are listed with abstracts. A list of personnel is included.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

TABLE OF CONTENTS

INTRODUCTION

The Atmospheric Sciences Division (ASD) is one of four subdivisions (along with the Environmental Chemistry Division, the Oceanographic Sciences Division and the Terrestrial and Aquatic Ecology Division) of the Environmental Section of the Department of Energy and Environment. The Division was established in 1975 as a successor to the former Meteorology Group, which was established in 1947 as part of the Reactor Department. The Group was later transferred to the former Health Physics Department and finally to the former Department of Applied Science.

Division scientists are engaged in a wide variety of basic and applied research primarily related to the transport, diffusion and removal of atmospheric pollutants originating from energy producing or using sources. The research program requires study of the characteristics of the lower atmosphere over a range of spatial and temporal scales and includes field experiments, continuous data collection, theoretical and modeling studies, data management and instrument development. The staff currently consists of eleven scientific and professional personnel and seven non-professionals including technicians, computer aides and a secretary. The staff is augmented by several consultants and part-time students. In addition, several projects are conducted in cooperation with personnel from other divisions.

Because this is the first ASD annual report, it seems advisable to describe the research facilities and major items of equipment used by Division personnel and to provide information on the scientific and professional staff as well as to describe current research programs and publications. Thus, this report includes five main sections: Facilities and Equipment, Current and Future Research Programs, Publications, and Personnel.

FACILITIES AND EQUIPMENT

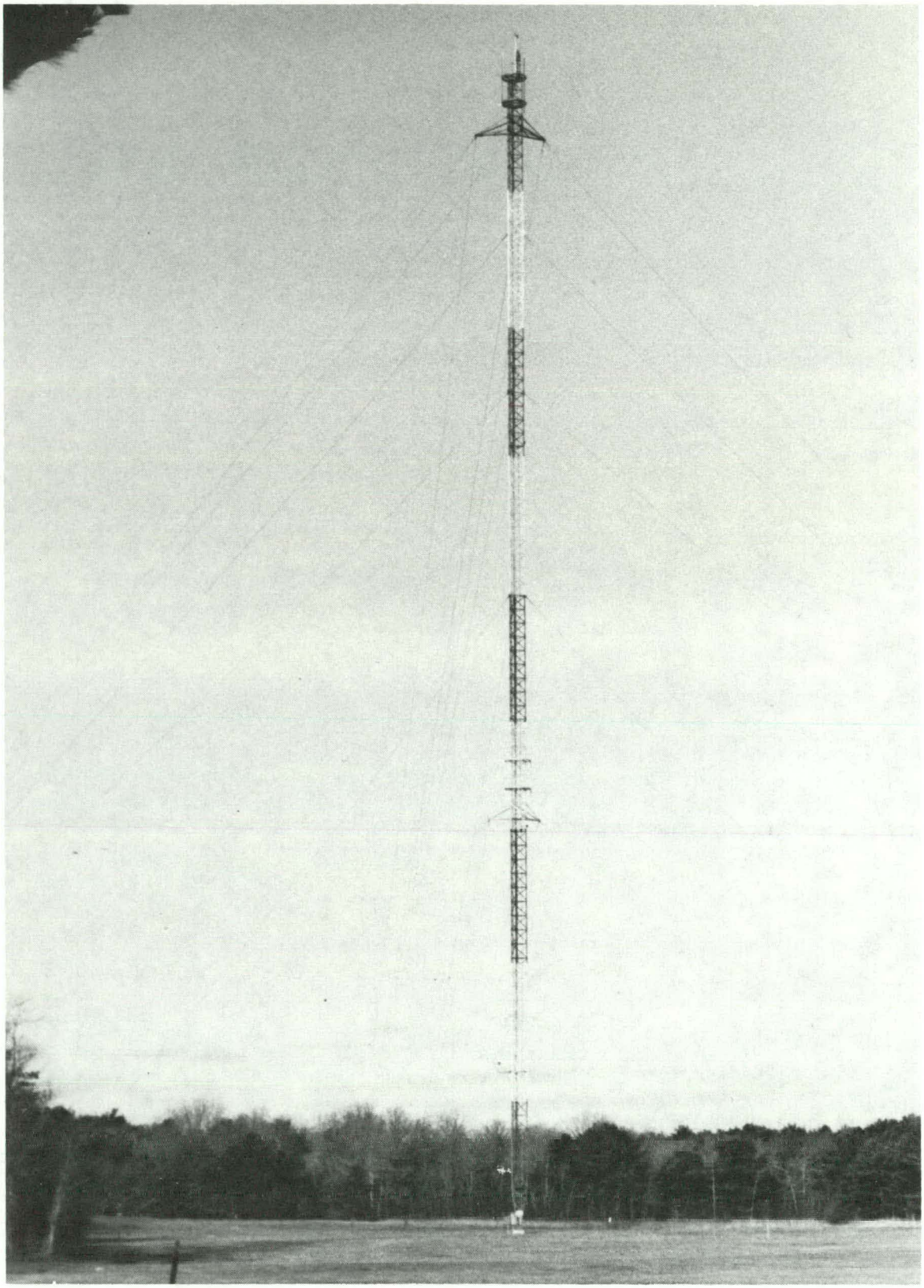

Figure 1. The 85-m tower TEN at BNL.

The facilities and major items of equipment used in the Division's scientific programs and service activities are described in this section rather than in the program descriptions since most are used in more than one program or activity. These descriptions are intended to document the current wide range of measurement and analytical capabilities available for future as well as current programs.

Facilities are described in four general groups:

1. Relatively permanent experimental, measurement, and calibration facilities at BNL,
2. Semi-permanent experimental facilities in the field,
3. Mobile experimental systems and platforms, and
4. Facilities for data processing analysis, storage, and display.

Some overlap occurs between these groups since some data processing, for instance, is performed in the field and on the aircraft. However, this grouping provides a convenient framework for the following descriptions.

EXPERIMENTAL AND MEASUREMENT FACILITIES AT BNL

Facilities at BNL provide local meteorological measurements for research, climatological and service activities, synoptic data for forecasting and research programs, and instrument calibration equipment.

Meteorological Measurements

The most important facility at BNL is the 85-m (280-ft) tower TEN (Figure 1) which was placed in service in May 1981 to replace the former 128-m ACE tower. The tower supports instruments for measuring wind direction and speed, vertical wind velocity and temperature at two levels. An Aerovane, a Gill vertical velocity sensor, and an aspirated YSI thermistor temperature sensor are mounted at the top and provide parameters needed for atmospheric diffusion calculations. Similar wind and temperature equipment is installed at the 11.3-m level to document low-level flow conditions and to permit calculation of wind and temperature profiles.

A microprocessor-controlled data acquisition system (Acurex, Autodata Nine) in Building 51 is used to monitor the output from the instruments on the tower and elsewhere. It can time-average (usually 1 hour) the incoming signals and transmit the processed data to recording devices. At the present time, the data is being recorded on a Kennedy 1610 Incremental Magnetic tape recorder from which climatological records are determined and stored on tape for future use.

All of the tower TEN information is also multi-plexed and sent by hard wire to a real time data acquisition system set up on site for emergency use. The data are also recorded on charts for backup and display purposes.

The total incoming solar radiation is measured by an Eppley pyranometer and the incident (direct) solar radiation is measured by an Eppley

pyrheliometer both mounted on top of Building 51 and recorded by Leeds and Northrop recorders in the Analysis Room.

A standard Weather Bureau instrument shelter, located just to the north of Building 51, houses a maximum and minimum thermometer set, a sling psychrometer, a self recording Friez-Bendix hygrothermograph for measuring temperature and humidity, and a 100-ohm copper resistance thermometer. Some of the measurements from the shelter are recorded there. Others are transmitted by hard wire into the Analysis Room for recording.

Two mercury barometers are located in the Analysis Room and are used as standards for checking a recording Friez-Bendix microbarograph which produces a record of pressure changes on a weekly basis for use in climatological programs and for forecasting purposes.

Precipitation is measured by a Friez-Bendix weighing-type rain gauge and by a Climet tipping bucket rain gauge. The weighing-type gauge has a set of barriers to break up the wind flow across the opening of the gauge to minimize errors induced by high wind speeds. The results from that gauge are recorded on a weekly chart attached to a spring-wound clock drive inside the recorder. The tipping bucket gauge produces an electrical impulse for each 0.01 inch of rain. The impulses are recorded on one channel of an operations recorder in the Analysis Room.

A beginning and end of precipitation sensor, designed at BNL (Raynor, 1955), is used to provide detailed precipitation information. The sensor output is also recorded on the operations recorder.

Precipitation Collectors

Two precipitation samplers are used to collect samples for chemical analysis. The Brookhaven Automatic Sequential Precipitation Sampler (Raynor and McNeil, 1979) (Figure 2) is located near Building 51 and collects hourly samples. A cover actuated by a precipitation sensor prevents dry deposition between periods of precipitation and a turntable inside the collector rotates periodically to bring collecting jars under the funnel sequentially. Time of cover openings and closings and times of sample change are recorded on the operations recorder.

An Aerochem Metrics Model 301 (HASL-type) precipitation collector used on an event basis is located in the field near TEN tower as part of the MAP3S precipitation sampling network. Cover openings and closings are recorded on the same operations recorder.

Synoptic Data Equipment

A Teletype Corporation teletype is time-programmed to provide weather observations and information from most NOAA stations in the northeast USA. The information is available for each hour of the day and is used to provide current and past weather data for research programs and for providing storm warnings and forecasts for essential BNL activities.

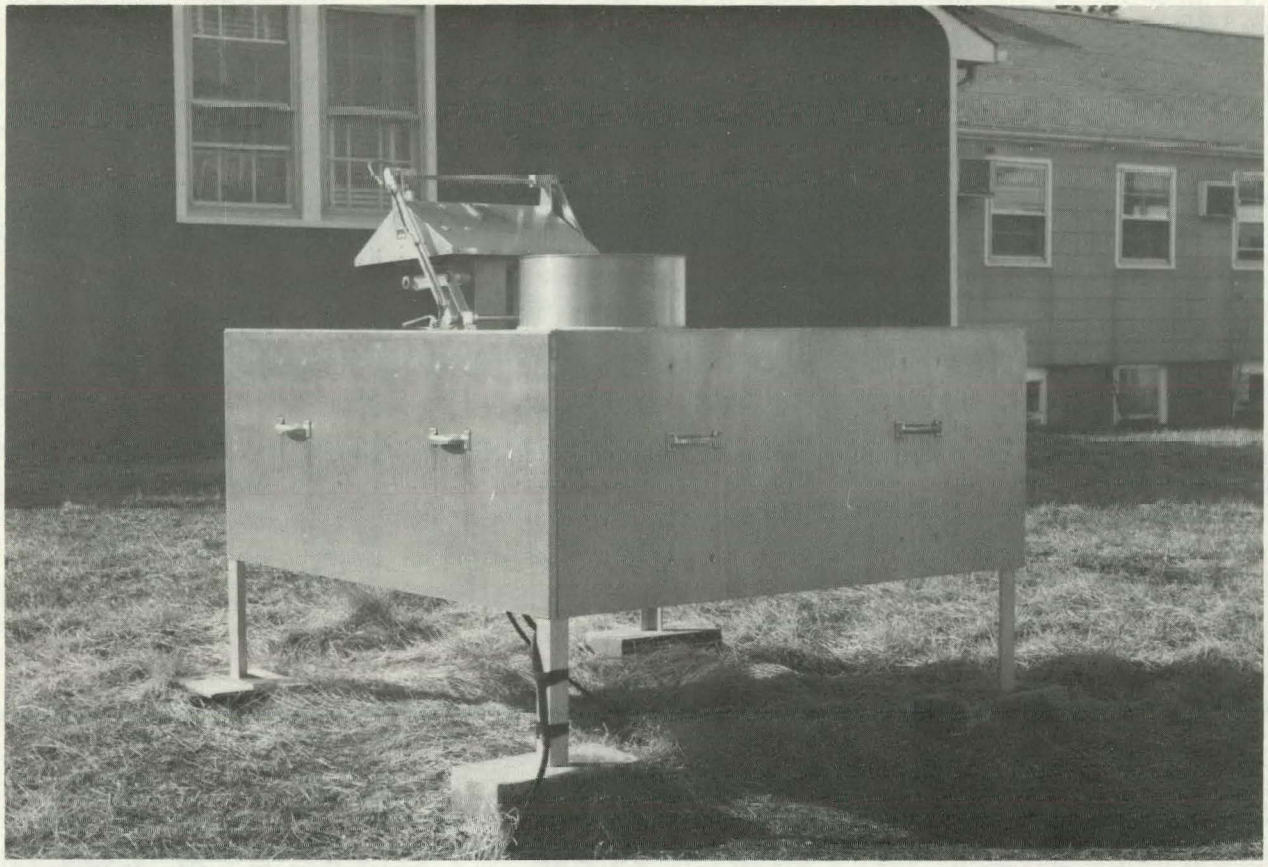

Figure 2. The Brookhaven Automatic Sequential Precipitation Sampler with cover open.

An Alden weather facsimile recorder is also time-programmed to produce weather maps including surface and upper levels. A wide variety of information is available from this recorder which is used to plan experiments and to aid in forecasting.

An Alden weather radar facsimile is also available to provide the latest weather radar maps at any of many locations throughout the United States by direct telephone dialing. The information is used mainly for planning and directing flights of research aircraft and for obtaining current severe weather information for alert purposes.

A link between the National Weather Service (NWS) computer in Suitland, Maryland and an on-site PDP 11/70 computer permits acquisition of all NWS bulletins including observations and forecast products in near real time. This data processing system is described in more detail below.

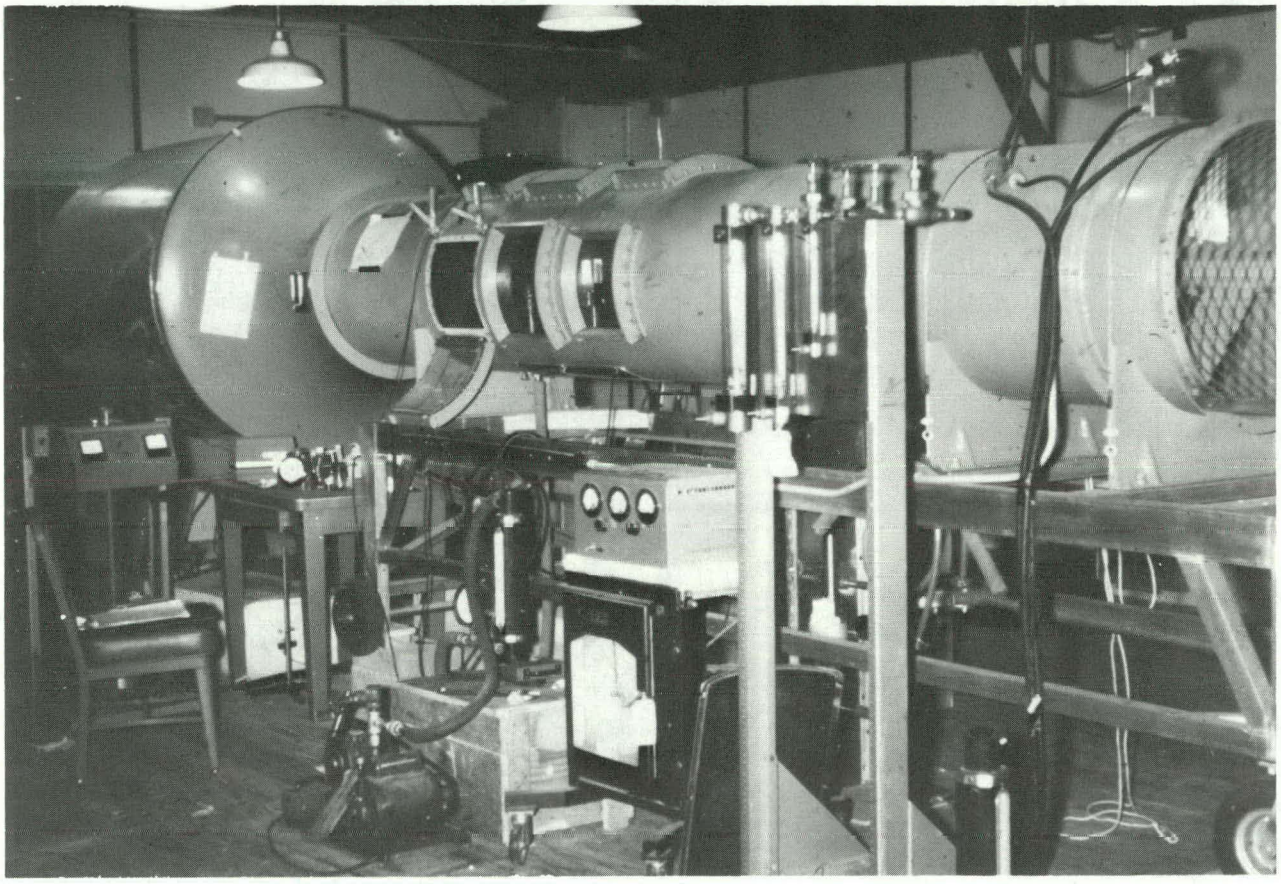

Figure 3. The ASD Wind tunnel.

Calibration Facilities

Facilities are maintained to calibrate the diverse instrumentation used in the research programs.

A wind tunnel (Figure 3) is used to calibrate all of the wind measuring equipment. The tunnel is 13 ft long with a 2-ft-diameter circular cross section. The tunnel flow is determined by a cup anemometer that has been calibrated by the National Bureau of Standards (NBS). The speed is variable from 0 to ~16 m sec^{-1} which satisfies most of the calibration requirements of the equipment under test. The tunnel has also been used to test wind flow around samplers and other objects using oil-fog smoke in the tunnel as a visible tracer.

A Standard Cabinet Company environmental test chamber is used to provide variable and controlled temperatures from -25° F to 350°F and relative humidity control from 20 to 95% over the temperature range from -25° F to 180° F. The working test space is 24 inches wide by 20 inches deep by 30

inches high which provides space to accommodate several thermometers and relative humidity sensors at the same time. Standard thermometers, whose calibrations can be traced to NBS standards, are used to provide dry and wet bulb temperatures for calibrating all other temperature and relative humidity (dew point) sensors.

A large walk-in environmental growth chamber is used for performing simulated atmospheric experiments where control of temperature, humidity, and sunlight is desired. The chamber is 2.5 meters high, 4.8 meters wide, and 7.0 meters long. The temperature and humidity can be controlled over normal atmospheric ranges and ultra-violet lights can duplicate solar ultra-violet intensities. The chamber is currently used by the Land and Freshwater Environmental Sciences Group in studies of the effects of acid rains on vegetation.

OFFSITE EXPERIMENTAL FACILITIES

A 25-m Upright Scaffold walk-up aluminum tower (Figure 4) is located near the ocean on the barrier beach at Tiana Beach, Hampton Bays (about 32 km from BNL on the south shore of Long Island). An instrument trailer is located in a fenced enclosure nearby. An Aerovane is mounted at the top and the wind speed and direction recorded on a chart recorder in the trailer. The tower is also instrumented to obtain mean winds at six levels, mean temperatures at four levels, vertical turbulence at three levels, humidity at one level, and three dimensional turbulence and fluxes at one level. The observations are analyzed by a mini-computer in real time and recorded on digital tapes. Sensors include cup anemometers, Gill propeller vanes for vertical turbulence, a vortex anemometer, and aspirated YSI thermistor temperature sensors.

A 16-m telescopic trailer-mounted tower (Figure 5) is stationed at a Southampton Town owned facility in Hampton Bays to study turbulence inland during diffusion experiments and to study marine air modification during onshore flows. The tower is instrumented with wind, turbulence, and temperature sensors at several levels. Data may be telemetered by the system described below to the Tiana trailer for recording on the data acquisition system there or recorded by a tape recorder and chart recorder in a box at the base of the tower.

An Aerovane is mounted at 10 m at Brookhaven Airport about 7.5 km south of BNL to provide wind data for coastal experiments. A similar instrument was formerly mounted at Smith's Point about 15 km south.

MOBILE EXPERIMENTAL SYSTEMS AND PLATFORMS

Aircraft

A Britten Norman "Islander" twin engine STOL type aircraft (Figure 6) is leased on a yearly basis and is equipped with "state of the art" equipment for making meteorological, atmospheric, chemical, and navigational measurements. A full description of the aircraft, its sensors, and recording system was given recently by Leahy (1981). It is used in several programs related to air pollution, precipitation chemistry and internal boundary

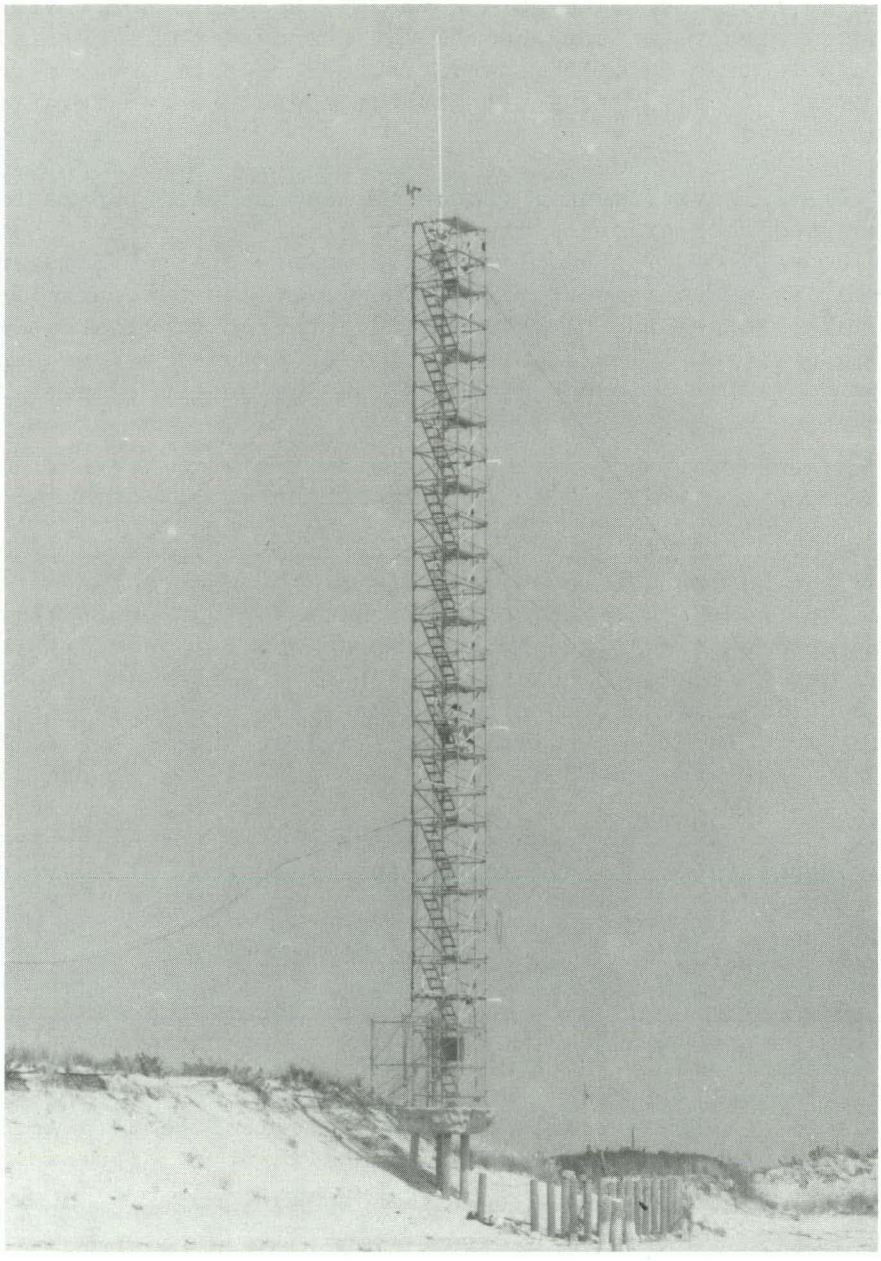

Figure 4. The 25-m tower at Tiana Beach.

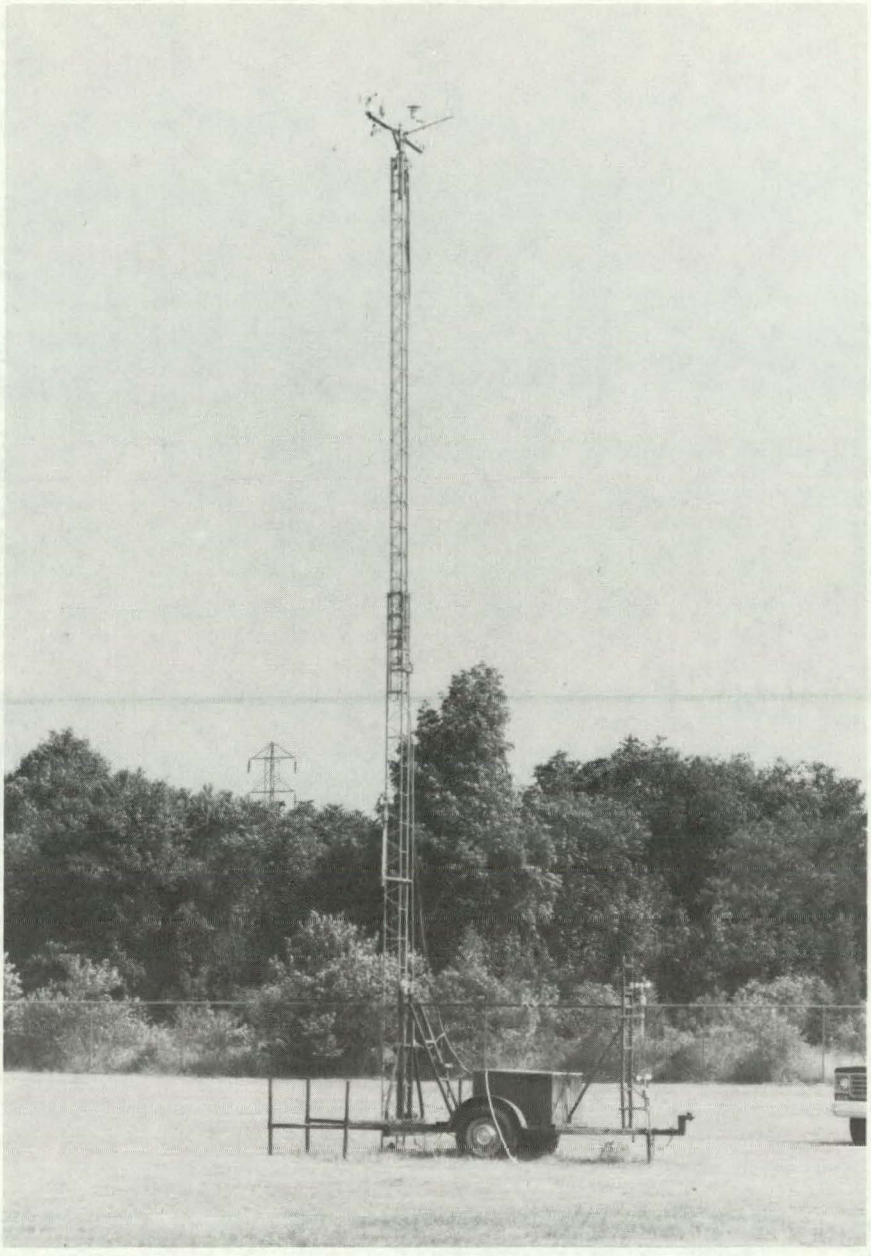

Figure 5. The trailer-mounted telescoping tower at Hampton Bays.

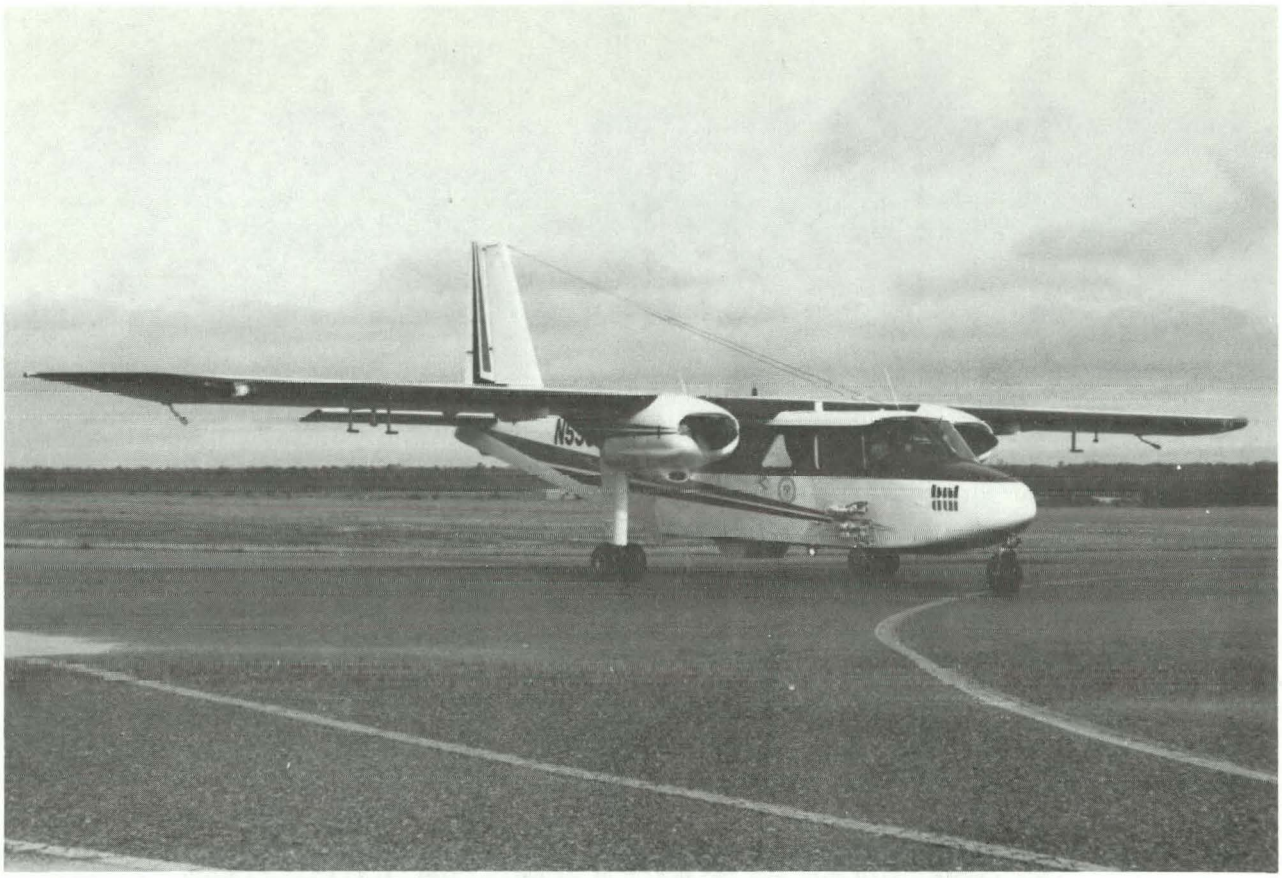

Figure 6. The Brookhaven Britten-Norman Islander research aircraft.

layer development, often in cooperative programs with the Environmental Chemistry Division. More detailed data on the aircraft and current instrumentation are given in Tables 1-3.

Boats

A medium-sized landing craft, LCM8 (Figure 7), on temporary loan from the U.S. Navy is maintained for use in air/sea, boundary layer, and coastal studies. It is an all aluminum, 74-ft long, sea-going vessel whose primary mission is to act as a platform for dispensing tracer material at predetermined distances from the shore. It has been used to transport and deploy oceanographic buoys and spars for studies associated with coastal meteorological and oceanographic programs. The vessel is equippped with radar, Loran-C, a depth finder, ship to shore radios, and a large derrick for loading and unloading heavy objects. It is normally docked at the U.S. Coast Guard station in Hampton Bays.

A 35-foot work boat (COBOLT) (Figure 8) is also used in air/sea and coastal experiments. It is also equipped with radar and stationed at the Hampton Bays Coast Guard station.

Table 1

AIRCRAFT SPECIFICATIONS

Type	Britten-Norman Islander, BN-2A
Engines	Twin 300 H.P.
Landing Gear	Fixed-tricycle
Electrical	70 amp 28 VDC alternators (2)
Empty Weight	5200 lbs. with BNL equipment aboard
Gross Weight	6600 lbs.
Fuel Capacity	168 gallons
Fuel Consumption	24-28 gallons per hour
Seats*	4 (Pilot, Co-pilot, 2 Observers)
Cruising Speed	120 Knots
Stalling Speed	40 Knots
Ceiling	12000 Feet
Range	700 Miles (0 winds)

*Co-pilot is required for certain missions.

Table 2

MEASUREMENT SYSTEMS

Navigational	
VOR (2)	
DME	Metrodata M-8 unit
Air Speed	
Indicated Air Speed	Rosemount 831 CP
Compass	Humphrey Gyro DGOY-0122-1
Altitude	CIC Model 7000
Radar Altimeter	Bonzer MK-10
Ground Speed	Singer SK 1000 (Doppler)
Drift Angle	
Meteorological	
Temperature, Ambient	Yellow Springs, 705
Temperature, Surface	Precision Radiation Thermometer
Dew Point	EG and G Model 137-3C
Turbulence	MRI Model 1120
Total Solar Radiation	Eppley Pyranometer Model 8-48
UV Radiation	Eppley UV Radiometer Model 14168
Relative Humidity	Weather Measures Model HM 111
Liquid Water Content	Cloud Technology Model LWH
Chemical (Real Time)	
NO, NO_x, HNO_3 (super sens.)	Teco 14B
NO, NO_2, NO_x	Monitor 8840
SO_2, SO_4	Meloy Modified
SO_2	Interscan 1230 SP
O_3	AID 560
SF_6	BNL Detector
NH_3	BNL Detector
Particulate	
Optical	MRI Nephelometer 1550
Sub Optical	CNC-2 General Electric
Discrimination	BNL Size Discrimination Aerosol Unit
Sample Collection	
Aerosol and Gas Filter ($SO_4^=$, H^+, $NH_4^=$, NO_3^-, SO_2, HNO_3)	High Volume Filter Pack
Cloud Liquid Water	ASRC Collector
Data System	
Tape	Metrodata Model 640
Chart Recorders	Soltec Dual Pen Model 6723 (4 each)

Table 3

MEASUREMENT SYSTEMS SPECIFICATIONS

	Range	Accuracy	Resolution	Time
Navigational				
VORS	0-360°	1°	0.36°	1 sec
DME	0-100 nautical miles	1 nm	0.1 nm	1 sec
IAS Rosemount (ΔP millibars)	0-50 mb (175 knots)	0.1 mb	0.05 mb	1 sec
Ground Speed (Doppler)	70-250 knots	0.2 knots	0.25 knots	2 sec
Drift Angle (Doppler)	40°L to 40°R	0.2°	0.1°	2 sec
Compass	0-360°	1°	0.36°	1 sec
Altitude CIC	500-15000'	100'	16'	1 sec
Altitude Radar	50-2000'	5%	4'	1 sec
Meteorological				
Temp. Ambient	±50°C	0.1°C	0.05°C	5 sec
Temp. Ground	-20°C to +40°C	0.5°C	0.1°C	1 sec
Dew Point	-20°C to +40°C	< 1°C	0.1°C	5 sec
Turbulence	0-10 $(cm^2/sec^3)^{1/3}$	2%	.01	3 sec
Solar Rad.	0 to 980 watts/m^2	1%	1 watt/m^2	5 sec
UV Rad.	0-57 watts/m^2	2%	0.1 watt/m^2	5 sec
Relative Humidity	0-100%	1%	1%	1 sec
Water Content	0.1 g/m^3 (low)	--	--	1 sec
	0-5 g/m^3 (high)	--	--	1 sec

Table 3 (cont.)

MEASUREMENT SYSTEMS SPECIFICATIONS

	Range	Accuracy	Resolution	Response Time*
Chemical				
NO, NO_2, NO_x	5 ppb-10 ppm	5-10 ppb	5 ppb	5 sec
SO_2 SO_4 (Meloy)	5 ppb-10 ppm	5 ppb	5 ppb	10 sec (upscale) 30 sec (downscale)
SO_2 (Interscan)	50 ppb-10 ppm	50 ppb	50 ppb	1 sec
O_3	2 ppb-10 ppm	2 ppb	2 ppb	0.5 sec
SF_6	5 ppt-1 ppb	5 ppt	5 ppt	5 sec
NO, NO_x, HNO_3 TECO 14B (super sens.)	0.1-1000 ppb	0.2 ppb	0.1 ppb	2 sec*
NH_3	0.2-1000 ppb	± 20%	0.2 ppb	2 min

*Each of the 3 parameters read once during a 25 second time cycle.

Particulate				
Nephelometer	0.40 b_{scat} (10^{-4} m^{-1})	10%	.05 b_{scat}	10 sec
CNC	$10/cm^3$ to $10^6/cm^3$	±20%	10 cm^3	#2 sec

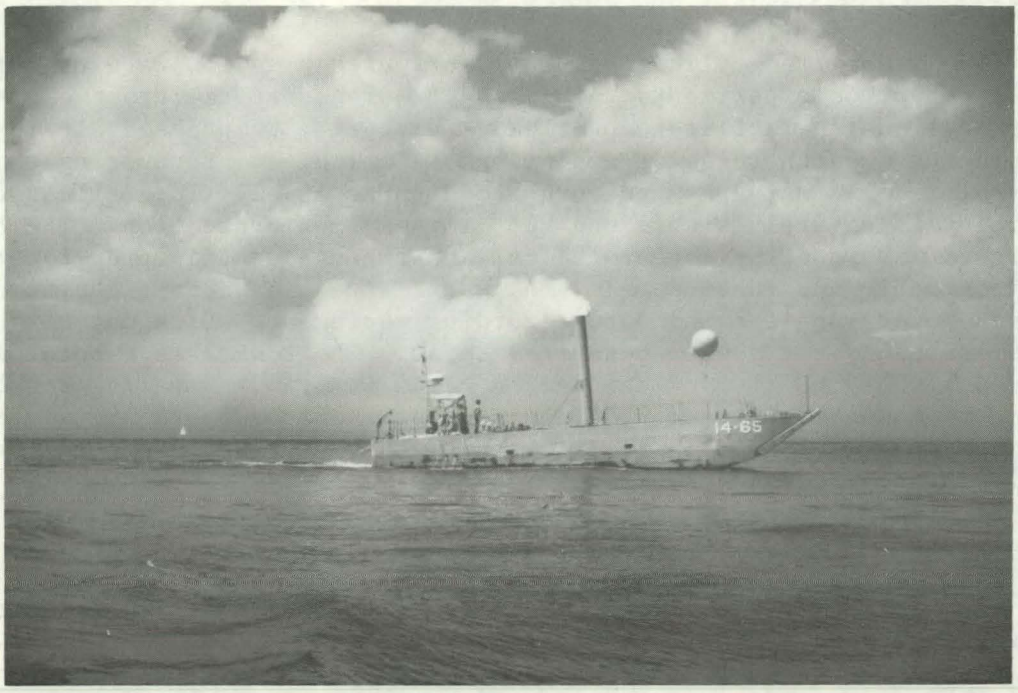

Figure 7. The research vessel LCM8 emitting oil-fog smoke.

Figure 8. The research vessel COBOLT.

Buoys

Two stabilized cylindrical buoys (Figures 9 and 10) are used for air-sea interaction experiments. They can be disassembled into two, three, or four sections to facilitate overland transport. Compressed air is stored aboard and the controls for deploying, trimming, and recovering the buoy are centralized in the superstructure above water level. The ballast control plumbing is entirely within the hull for maximum protection. The buoys are designed for mounting meteorological instruments on the upper tower and oceanographic instruments below the water line. A water-tight compartment houses power supplies and data recording equipment. Data may also be telemetered by the system described below. The tower has a total length of 29.6 m with 19 to 21 m of the length below water. At sea it is held in place by a mooring system. Complete details of the buoys are given by Huszagh *et al*. (1979). A description of the instrumentation and data acquisition system is given by SethuRaman *et al*. (1978).

Data System

SATDAS (Satellite Data Acquisition System) (Figure 11) is a data acquisition system utilizing a satellite telemetry link (Lobecker *et al*., 1980). It is used for air-sea interaction and oceanographic experiments and has been used on the buoy and at the Hampton Bays tower. It is microprocessor-based with all functions under software control. These include data interrogation and acquisition, timing control, tape storage, and data telemetry. Data processing programs are included to calculate averages, variances and covariances. Diagnostic routines are included for system self-test. The use of the microprocessor has resulted in a very simple configuration with an accordingly high level of reliability. Telemetry to shore is via the GOES (Geostationary Operational Environmental Satellite). SATDAS provides a unique combination of *in situ* processing, system self-check, on-board recording, and satellite telemetry.

Vehicle

A Dodge step-van with a 15 kw Onan electric generator is used as a mobile instrument platform in many field experiments. The van is equipped with electric heaters and an air conditioner and has an inside working area of 2.1 x 4.6 m. Bench and rack space is available for atmospheric, chemical, and meteorological instruments and recorders. A roof-mounted air scoop is used to bring in outside air during tracer experiments and air pollution studies.

Towers

In addition to the tower at Hampton Bays, several other 16-m telescopic E-Z Way trailer-mounted towers are available for use in remote or temporary locations.

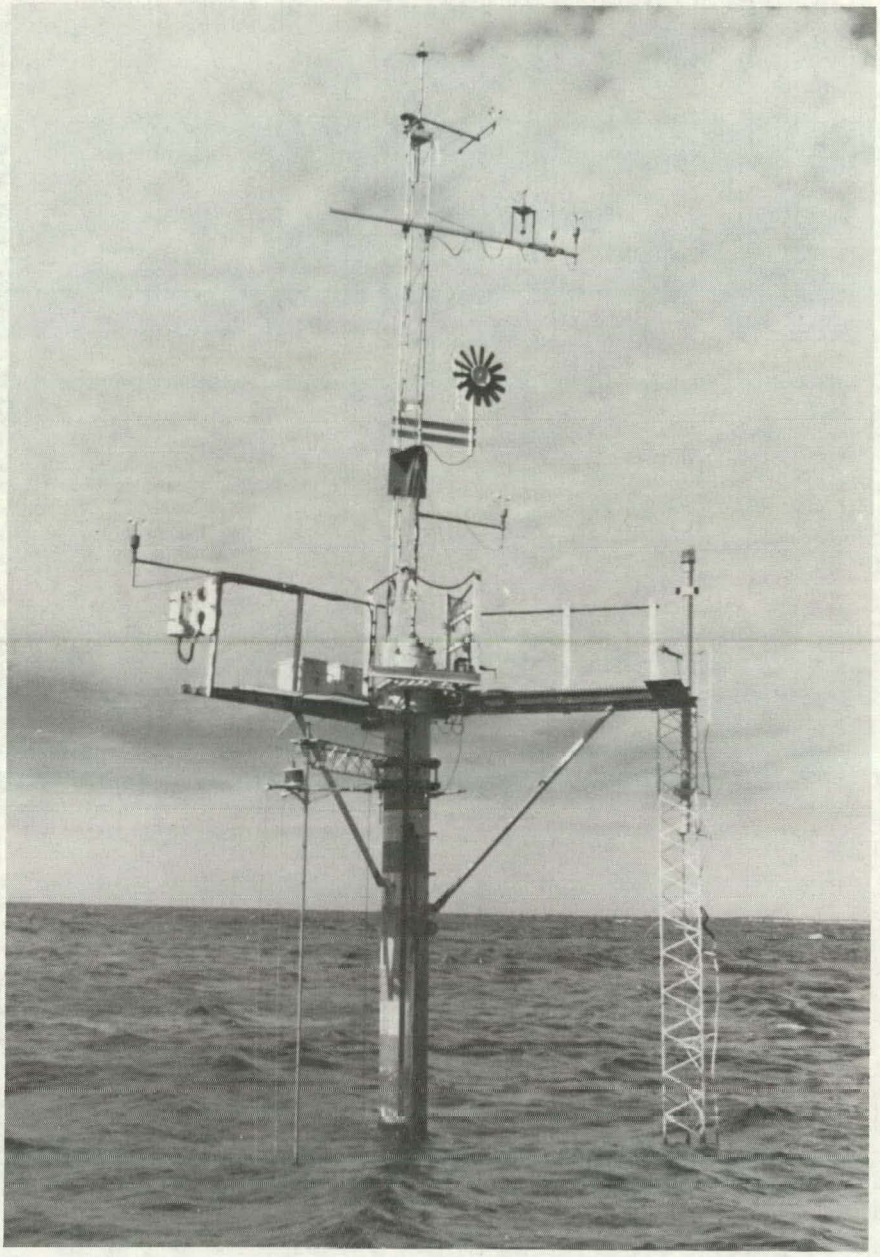

Figure 9. The Brookhaven air-sea interaction research buoy at sea with meteorological instruments and wave staff.

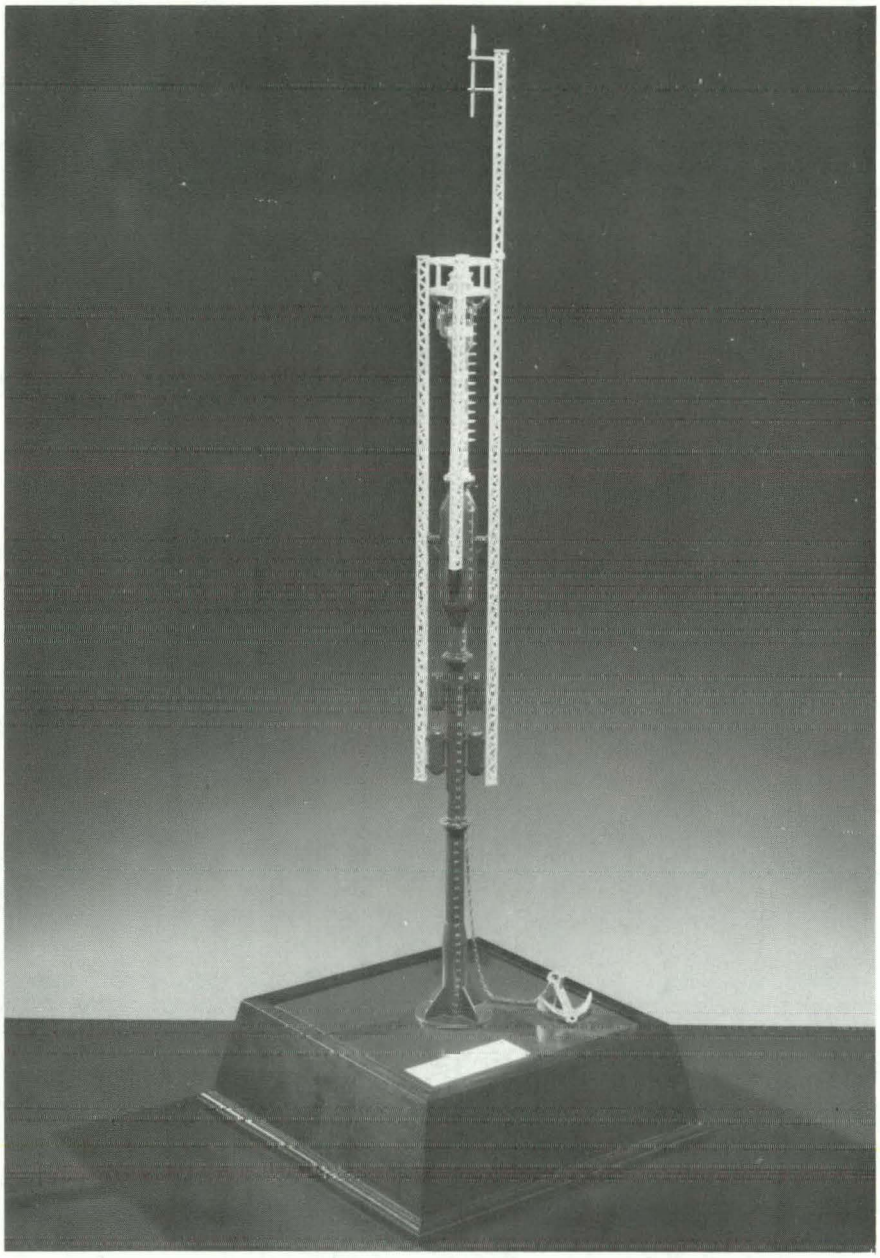

Figure 10. Model of Brookhaven air-sea interaction research buoy.

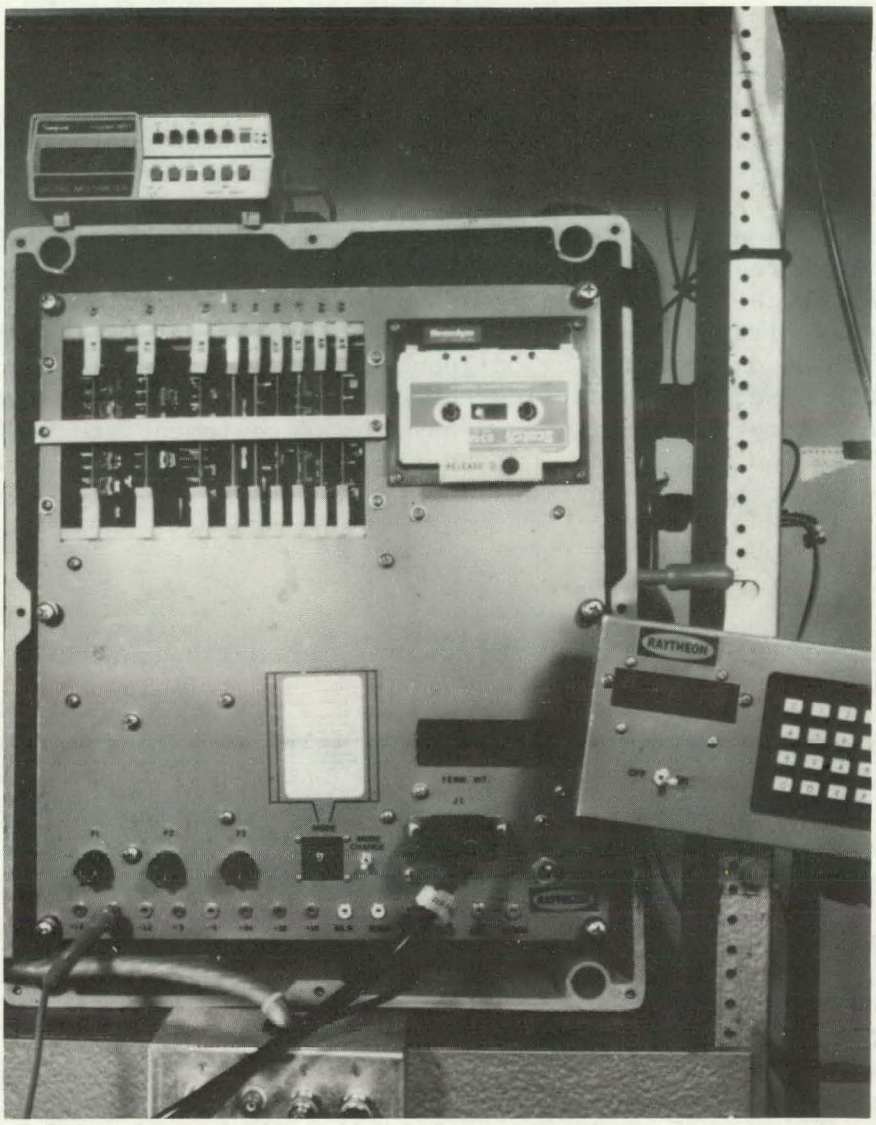

Figure 11. Microprocessor-based data acquisition system through satellite telemetry used in BNL boundary layer studies. This system provides real time statistical parameters of atmospheric variables and is designed for use on air-sea interaction buoys or other remote locations.

Remote Sensor

An Aerovironment monostatic acoustic radar is mounted on a trailer for use in the field. Both transmitter and receiver are mounted in a sound-insulating enclosure open at the top. The sounder may be powered by AC current from a line or a portable generator but two nickel cadmium batteries are normally used for remote operations. The sounder emits a periodic pulse of sound which is reflected by discontinuities in the atmosphere giving information on turbulence and temperature structure.

Balloon Systems

Another instrument for investigating atmospheric structure is an Atmosphere Instrumentation Research Co. (AIR) microcomputer-controlled tethersonde and airsonde system. This is a portable system for determining dry and wet bulb temperatures, pressure and wind speed and direction from ground level to altitudes as high as 1,000 m. It includes an electric winch for deploying a tethered 3.25 m^3 red plastic balloon and a sensing package (tethersonde) which transmits information to a ground station via telemetry. Accessory airsondes are also available for special use and have been utilized at times on free flying balloons. The AIR system is incorporated in supplementary meteorological instrumentation for use in emergency situations at BNL. Three theodolites and associated equipment are used to determine wind direction and speed aloft by pilot balloon soundings. They are frequently used at remote locations in support of various experimental programs.

Boundary Layer Observation System

A number of the instruments and equipment described above have been assembled in a Boundary Layer Observation System for field use in remote locations. These include the mobile towers and selected instruments, the tethersonde system, a pilot balloon system, and a mini-computer to process, display, and record means, variances, and cross-variances in real time. Versions of this system have been used in India and at the Gulf of Mexico.

Tracer Systems

Two types of tracers and associated equipment are used in diffusion experiments, oil-fog smoke, and sulfur hexafluoride (SF_6) gas. Oil-fog smoke is used as a visible tracer material because it can be seen, photographed, and measured rather easily. Two dual oil-fog generators (Dyna-Fog 400B) heat a special oil to its vapor point and upon cooling condenses it to oil-fog droplets in the 0.5-micron-diameter size range. They are small enough to act as aerosols and have negligible settling velocities. Thus, they follow atmospheric motions with no deviation. Figure 12 shows a generator with only one unit in operation. Smoke emitted from a generator on the LCM was shown in Figure 7.

Oil-fog concentration can be measured using instrumentation for detecting small particles such as the Meteorology Research, Inc. (MRI) integrating nepholometer (1550). A nepholometer is normally mounted in the Brookhaven van and measures concentrations during traverses across the plume at various distances downwind of the source. During stable atmospheric conditions, with little crosswind diffusion, the oil-fog can be measured many kilometers downwind but only a few kilometers during unstable conditions. Thus, another tracer material and measuring technique suitable for longer distances is used.

Sulfur hexafluoride (SF_6) gas emitted in relatively small concentrations to the atmosphere during unstable conditions can be traced for hundreds of kilometers downwind. To obtain integrated concentrations of SF_6

Figure 12. Smoke generator emitting oil-fog smoke from one nozzle.

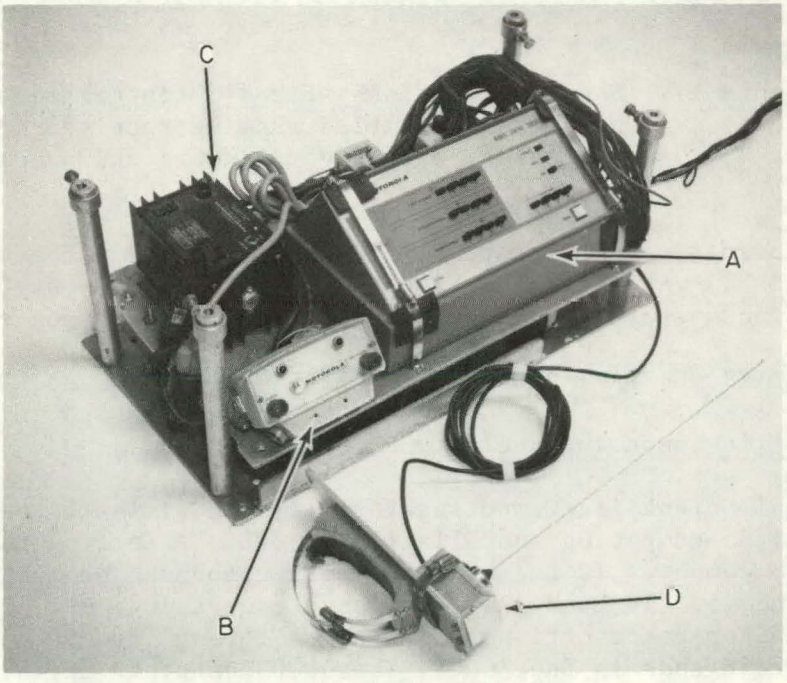

Figure 13. Encoding and transmitting portions of radio-controlled air sampling system mounted for aircraft use showing the encoder (A), radio (B), inverter (C), and antenna on strut mount (D).

Figure 14. Sampling portions of radio-controlled air sampling system disassembled showing receiver-decoder, batteries, sampling cylinders and junction box.

at selected crosswind arcs, a portable radio-controlled sampling system (Figures 13 and 14) was devised at BNL (Raynor, 1978). Twenty of these portable sampling systems are now routinely used in diffusion experiments.

FACILITIES FOR DATA PROCESSING, ANALYSIS, STORAGE AND DISPLAY

Central Scientific Computing Facility

The Central Scientific Computing Facility (CSCF) is the major general purpose scientific computing installation at BNL. A Control Data Corporation (CDC) 7600 computer is the most powerful component of the CSCF configuration. The 7600 is used only for batch processing; all input/output tape staging and operator actions are handled through two CDC 6600 computers which act as front ends to the 7600. The 6600 computers are also available for interactive as well as batch processing. Peripheral hardware includes disk drives, tape drives, card readers, line printers, and communication controllers. Offline graphics equipment supported include an Information

International Inc. FR-80 COM recorder which generates output on microfiche, 35 mm or 16 mm film or 8-1/2" x 11" printer ready hard copy and a Versatec flatbed 36-inch wide plotter. A number of online graphics terminals are available as well.

The CSCF provides a large complement of software support packages including FORTRAN compilers, routines for sorting and merging data files, routines for reformatting data files, packages for statistical and mathematical analyses such as the International Mathematical and Statistical Library Inc. (IMSL), the Biomedical Computer Programs (BMDP), and the Statistical Package for the Social Sciences (SPSS). Graphical software available includes DISSPLA, CALCOMP, and Advanced Graphics II. Data base management packages include SYSTEM 2000 and SIR.

BNL is also a participant in ARPANET which is an operational, resource sharing, host-to-host network linking a wide variety of computers at research centers sponsored by the Defense Advanced Research Projects Agency (DARPA) and other Department of Defense (DOD) and non-DOD activities in the continental United States, Hawaii, Norway, and England.

ASD Facilities

The Atmospheric Sciences Division is linked to the CSCF by a remote batch station housed in Building 51 and consisting of a card reader, printer, and small computer-controlled cathode ray tube terminal. The station is linked to the CSCF by dedicated telephone lines. Data transmission is 9600 baud, synchronous. In addition, interactive communication with the CSCF is possible both by dial-up lines through portable terminals and by hardwired lines through a Gandalf PACX (Private Automatic Computer Exchange). The PACX connection makes communication possible between two Tektronix 4014 graphics terminals located in the ASD building and either of the CSCF's 6600's, the ASD's PDP 11/70, and the CSCF's recently acquired VAX computer. Communication on PACX lines is asynchronous at speeds ranging from 1200 to 9600 baud.

The ASD is at present working on two special purpose LSI 11/02 computer systems which will be used for field work--one in the Islander aircraft and the other for ground based field experiments.

PDP 11/70 Computer

A communications link with the National Meteorological Center (NMC) in Suitland, MD provides computer access to weather data in real time. The data are received at BNL by a DEC PDP 11/70 mini-computer via an ATT leased line. Once at BNL there are several options for the data. Much of it can be looked at in real time in a format similar to Circuit "A" and Circuit "C" teletype data. Computer codes have been written to decipher some of the meteorological codes and write floating point files. These files can then be printed out, or graphically displayed, making use of the Gould printer/plotter or Tektronix facilities.

The core of the BNL-NMC link is the PDP 11/70 computer. The computer is shared at BNL with the Oceanographic Sciences Division. Currently, the system has 1.25 megabytes of memory, two large disk drives, several smaller disk drives, and a 9-track tape drive, all housed in the Applied Math Building. In addition, there is a Gould 22-inch printer/plotter and a Data Products 600-line-per-minute printer in the ASD building. Individual communication with the computer is accomplished by two high speed (9600 baud) direct lines used principally for printing and plotting, or by several slower speed dial up lines through portable terminals.

REFERENCES

Huszagh, D., W. Ripperger, and S. Fink, 1979: Design, construction, and initial operation of the BNL-coastal transport and diffusion, air/sea interaction research buoy. BNL-51111.

Leahy, D., 1981: The Brookhaven National Laboratory Atmospheric Sciences Aircraft. BNL 28102R.

Lobecker, R.N., S. SethuRaman and G. Field, 1980: SATDAS-for air-sea interaction data acquisition using satellite telemetry. Bull. Amer. Meteor. Soc. 61: 1212-1222.

Raynor, G.S., 1955: The rotary rain indicator, an electrical precipitation time recorder. Bull. Amer. Meteor. Soc. 36: 27-30.

Raynor, G.S., 1978: A radio-controlled sampling system for diffusion experiments. J. Appl. Meteor. 17: 1619-1624.

Raynor, G.S. and J.P. McNeil, 1979: An automatic sequential precipitation sampler. Atmos. Environ. 13: 149-155.

SethuRaman, S., W. A. Tuthill and J. McNeil, 1978: Instrumentation and data acquisition system for an air-sea interaction buoy. Bull. Amer. Meteor. Soc. 59: 1102-1112.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY OF RESEARCH ACCOMPLISHMENTS

This section provides a brief summary of research activities and accomplishments of the Atmospheric Sciences Division arranged by topic or subject area. The following section RESEARCH PROGRAM DESCRIPTIONS includes more complete descriptions of each program individually.

MODELING PROGRAMS

Three programs in the Atmospheric Sciences Division (ASD) are concerned primarily with development, improvement and validation of numerical models. Many of the field and laboratory studies and data management and analysis activities described below are performed in support of the modeling programs.

MAP3S/RAINE Modeling and Analysis

A primary goal of the MAP3S/RAINE modeling program sponsored by EPA is to realistically simulate the dispersion, chemical reactions and deposition of the major precursors and components of acidic wet and dry deposition. Earlier efforts aimed at development and improvement of a Lagrangian model but recent emphasis has been placed on development of a comprehensive Framework Eulerian model which would be usable at all participating Laboratories and could be operated on a variety of computers. The approach being used is to design, develop and document a modular computer code so that various modules can be developed independently and fitted into the Framework model.

Major aspects of this modeling effort include the logical ordering of the calculations, internal data communication, external data communication and user input/output. Operational modules include four components: 1. Development of a numerical scheme for the dispersion, deposition and linear reaction of the various pollutant species; 2. Inclusion of a software package to accommodate the nonlinear interaction of the chemical species; 3. Extension of the model to three dimensions by a layer approach for the vertical direction; and 4. Applications of the model to realistic conditions requiring objective meteorological analyses and gridded emissions distributions serving as inputs to the model.

The pseudospectral method was chosen as the dispersion algorithm together with a variable grid spacing mesh. Work is underway on a nonlinear chemistry module and a precipitation scavenging module.

Interregional Air Quality

The Interregional Air Quality program sponsored by DOE is designed to develop and use the analytical and computational tools necessary to analyze the environmental consequences of our present and planned energy related policies. Recent efforts include the writing of an information book on the nitrogen oxides and calculation of the effect of stack height on air quality and deposition impacts of SO_2 and SO_4.

Probability Modeling of Atmospheric Transport and Diffusion

This program funded by the Department of Defense is concerned with developing advanced diffusion and transport models using probability concepts applicable to the problem of battlefield visibility. The scientific approach has been to use surface boundary layer meteorological parameterization based on similarity theory with probability density functions for the concentration of smoke as derived from the conservation of mass equations.

FIELD AND LABORATORY STUDIES

Field and laboratory studies are included in eight of the programs conducted by the Division. Related or similar programs are summarized together here.

Precipitation and Atmospheric Chemistry Studies

Four programs involve precipitation chemistry and related topics. A variety of studies are in progress under the Multistate Atmospheric Power Production Pollution Study/Regional Acidity of Industrial Emissions (MAP3S/RAINE) program sponsored by EPA. All are concerned with the atmospheric aspects of the acidic precipitation problem including emission, transport, diffusion, chemical transformation and wet deposition. The short-period changes in chemical composition that occur during precipitation events and their relationship to concurrent and preceding meteorological conditions and events are studied in a sequential precipitation sampling program. Hourly samples are analyzed for pH, conductivity and the concentrations of major ions. Both concentration in precipitation and amount of wet deposition to the surface are found to be related to synoptic events, to precipitation type and rate and to other meteorological conditions. Relationships between chemical species allow inferences to be made concerning atmospheric mechanisms. Trajectory analyses are identifying probable source regions.

Preparations are in progress for a study of the effects of urban sources on regional deposition chemistry. A network of precipitation collectors will be operated during selected precipitation events around a major urban area. Concurrent atmospheric chemistry and meteorological measurements will be made at ground level and from an aircraft when feasible. Differences in upwind and downwind precipitation chemistry will be related to source emissions, atmospheric chemistry and meteorological conditions to determine the effect of the urban source on downwind precipitation composition.

Equilibrium effects on precipitation scavenging of aerosols and gases are being studied in a set of field and laboratory experiments. Measurements of pertinent components in the aerosol sulfate, nitrate-gaseous ammonia, nitric acid systems are being taken in real time or over short durations near ground level and from the BNL aircraft under both clear air and precipitation conditions. A major goal is to determine if models of scavenging processes can be simplified. A number of field measurement experiments have been conducted at several locations. Additional experiments are needed before definitive results are known.

Cloud processing studies are in progress to understand the role of clouds in the transformation and relocation of pollutants in the atmosphere to aid in modeling the mechanisms by which pollutants are produced or scavenged by clouds and removed from the atmosphere by precipitation. Vertical profiles of important ionic species and their gaseous precursors are measured from aircraft up through cloud layers. Cloud water is collected for subsequent chemical analysis and cloud liquid water content is measured using newly developed or recently installed instrumentation on the BNL aircraft. Results are expected to provide improved understanding of the role of clouds in the wet deposition process.

The interlaboratory MAP3S/RAINE OSCAR (oxidation and scavenging characteristics of April rains) study was conducted in April 1981 to examine the dynamics and chemical features of selected frontal storms, to assess the spatial and temporal variability of precipitation chemistry, to provide an extensive data base for model development, to develop increased understanding of wet removal mechanisms and to identify source regions. A thirty-seven station sequential sampling network was set up in the northeastern United States and operated during three precipitation events. A forecast center was operated at BNL and atmospheric chemistry measurements were taken at ground level and from research aircraft. Chemical analysis of the samples obtained is still in progress but preliminary results show large short period variability in local precipitation composition and consistent regional scale patterns.

The Meteorological Effects of Thermal Energy Release (METER) program sponsored by DOE is a study of the inadvertent weather modification effects of power plants which employ cooling towers and cooling ponds. One phase of the program was designed to study wetfall chemistry around a large power plant as well as the temporal and spatial variability of precipitation. Earlier phases of the program were conducted by Oak Ridge and Pacific Northwest National Laboratories but BNL became involved in the last field experimental period and in data analysis which is still in progress.

A study of the rainout and washout of nitrogen oxides and oxyacids has been conducted for the Federal Aviation Administration by the Environmental Chemistry Division (ECD) with some participation by Atmospheric Sciences Division personnel. This study included a literature review, fundamental laboratory studies of the solubility equilibria and reaction kinetics important in the aqueous chemistry of nitrogen oxides and oxyacids in the atmosphere, selected field investigations of rainout and washout of these species in the lower troposphere and modeling the rates of rainout and washout.

A study of the cloud water acidity measurements and formation mechanisms is being conducted for the Electric Power Research Institute by ECD and ASD investigators. This program is designed to investigate those processes by which acidic materials enter into cloud droplets and subsequently into precipitation. Objectives are to measure concentration fields of relevant species within clouds and in the in-flow region, to examine equilibria and to evaluate rates of aqueous-phase chemical reactions occurring in cloud liquid water. Cloud liquid water is being collected by

aircraft-mounted devices for subsequent chemical analysis. Instrumentation has been designed to permit sampling of air within clouds after removal of liquid droplets.

Boundary Layer Studies

Three programs involve meteorological investigations of the structure of the lower atmosphere, principally in coastal regions.

The Planetary Boundary Layer Studies at Land-Sea Interfaces program, sponsored by DOE, is designed to obtain an understanding of the meteorological processes that occur in or are unique to coastal zones and that affect the siting, operation or safety of power plants or other energy-related facilities or activities in coastal zones. A goal is to develop an operational predictive capability for describing diffusion from coastal or offshore sites.

This program has been conducted since 1972 and includes experimental studies of diffusion in coastal zones, an investigation of coastal internal boundary layers using airborne, tower-based and remote sensors, studies of marine meteorology and air-sea interactions and a study of the transport and diffusion climatology of the U.S. east and Gulf coasts. Current emphasis is in studies of diffusion in the transition region where air is modified and turbulence changes as air flows from water to land. This program has led to a number of important instrumental developments described in the Program Description. Important accomplishments include documentation of diffusion rates over the water and at the coast as a function of meteorological and surface conditions and determining the slope and equilibrium height of coastal internal boundary layers as a function of upwind lapse rate, land-water temperature differences, surface heating, and wind speed. Internal gravity waves over the ocean were studied and their effect on diffusion documented. Scales of turbulence over water were found different from over-land values.

As part of the Monsoon Experiment (MONEX) conducted under The Global Atmospheric Research Programme (GARP) of the World Meteorological Organization (WMO) a field experiment funded by NSF was conducted on the shore of the Bay of Bengal, India. Fluxes of momentum, heat and water vapor were measured from a 10-m tower on the beach, mean meteorological measurements were made nearby and wind speed and direction in the boundary layer were obtained with pilot balloon soundings. Data showed that the direction of the vertical heat flux changed with synoptic conditions, a finding relevant to the air-sea interaction processes causing cyclogenesis over the Bay of Bengal. Data analysis is still in progress.

Offshore Coastal Diffusion Studies in the Gulf of Mexico funded by the American Petroleum Institute were performed (in conjunction with the Stanford Research Institute) in support of diffusion experiments from an offshore oil-drilling platform during the summer of 1981. Meteorological measurements were made from a 10-m tower on the beach at Cameron, Louisiana. Periodic pilot balloon soundings were made and SF_6 tracer gas and oil-fog smoke were released from the platform. Analysis of the data is in

progress. A similar experimental period will take place early in 1982 to document winter conditions.

Aircraft Operations

Aircraft operations are performed in support of all research programs using the BNL Islander research aircraft. Continued maintenance, calibration and upgrading of meteorological, chemical and navigational instruments is an important part of the program. Recent additions include two cloud water collection devices and new or improved instruments for measurement of gaseous ammonia, NO_x and nitric acid and sulfur dioxide and aerosol sulfur.

DATA MANAGEMENT AND ANALYSIS

One program is concerned largely with management of data collected in experimental, observational and monitoring programs. Three others involve analysis of data collected in earlier experimental or observational programs.

MAP3S/RAINE Central Data Coordination

The Central Data Coordination task of the EPA sponsored MAP3S/RAINE program collects, integrates and disseminates experimental data generated by MAP3S and collaborating programs and auxiliary data needed by MAP3S program participants. A source emissions inventory has been compiled for particulates, SO_x, NO_x, hydrocarbons and CO covering the United States and Canada. Air quality data from the ground station network of the Sulfate Regional Experiment and from the EPA National Aerometric Data Bank are available for analysis and model comparison.

Precipitation chemistry data from the MAP3S network are on file and other precipitation chemistry data are being obtained. Data collected under the OSCAR experiment are being compiled. The meteorological data base needed by the Heffter Interactive-Terminal Transport Model is available for interactive use.

Northeast Regional Oxident Study (NEROS)

BNL personnel participated in the experimental phases of the EPA sponsored NEROS program in the summers of 1979 and 1980. The program was designed to provide experimental data to develop a regional scale photochemical air quality model. The BNL aircraft participated in the experiment in both years and the BNL mobile van with air sampling instruments was stationed in the Baltimore area in 1980. BNL meteorologists operated a forecast center at BNL in 1979 and assisted in operation of a forecast center at Baltimore in 1980. Current activities include data analysis and meteorological documentation of each aircraft mission.

Technical Assistance for Radioactive Materials Released from Nuclear Power Plants

This program involves preparation and management of a data base on nuclear power plant emissions as reported to the Nuclear Regulatory Commission (NRC) by plant operators. Annual reports are prepared and data made available to users.

Meteorological Service

The purpose of this program is to provide meteorological information and services to other Laboratory departments and users elsewhere. The program requires the installation, calibration, maintenance and operation of meteorological facilities and instruments, data reduction, conversion of data into usable forms and establishing and updating meteorological and climatological data bases. Weather information facilities such as teletype and facsimile are maintained. Forecasts are prepared for routine Laboratory use and emergency situations. Diffusion calculations are performed for the Reactor Division and the Safety and Environmental Protection Division. Data are provided for scientific programs in other departments and for various operational purposes. The climatological record has become an increasingly valuable resource and is available on tape from 1960 to the present.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

RESEARCH PROGRAMS

Title: MAP3S/RAINE Modeling and Analysis

FY 81: $201,000

FY 82: $229,000

Principal Investigators:
Paul Michael
Aristides A.N. Patrinos
Sponsor: Office of Research and Development, EPA

The MAP3S/RAINE program is a comprehensive multilaboratory program aimed at gaining an understanding of the atmospheric processes that control the wet and dry deposition of pollutants. The development of numerical models to simulate the dispersion, reaction, and deposition of the major precursors of "acid rain" is an integral part of the approach to develop a rational policy with regard to this problem. Realistic numerical models can serve as significant tools in the formulation of effective strategies in emissions control, energy source substitution, and impact assessment. Sensitivity experiments and alternative scenario simulations represent an aid to successful decision making in the continuing controversy between energy needs and environmental considerations.

It is recognized that Eulerian models possess substantial advantages over the Lagrangian models in the simulation of realistic flows in the atmosphere. While trajectory models are valuable in providing satisfactory estimates of source-receptor relationships, they fall short in modeling complex flow situations which represent the majority of "real" and relevant cases of air pollution. It is with this knowledge in mind that a general Framework model is being developed. The modular structure of the code will permit the rapid incorporation of state-of-the-art scientific advances and a flexible application to a range of problems by a variety of investigators. Particular emphasis is placed on achieving straightforward procedures for operating this numerical code.

It is apparent that the successful development of a Framework model depends on a variety of disciplines. Consequently, it is imperative that successful coordination be maintained with other research groups which are qualified to contribute certain state-of-the-art modules. Examples of such contributions include the nonlinear chemistry software package which is being developed jointly with BNL's Environmental Chemistry Division and the precipitation scavenging module expected from PNL. All meteorological modules of the code will benefit from continuing research activities on atmospheric dispersion and deposition. The incorporation of realistic flow fields from observed data is viewed as a crucial item requiring effective interfacing with state-of-the-art scientific efforts.

The technical approach to the development of a Framework model concentrates on the optimization of the various modeling procedures. Special procedures are required so that: a) model development can be carried on by a number of people; b) alternate parameterizations of specific processes can be used while others are held constant; c) the model may be easily updated as research results become available; and d) the computer codes produced can be transferred to other users and operated on a variety of computers. The

approach being used is to design, develop and document a modular computer code to serve as a framework; central to the design and development is the definition of programming standards and protocols.

Four major aspects have been identified: the logical ordering of the calculations, internal data communication, external data communication and user input/output.

With respect to the operational modules of the model, work is viewed in terms of four components:

a. Development of a numerical scheme for the dispersion, deposition, and linear reaction of the various pollutant species satisfying various conditions of accuracy and conservation.

b. Inclusion of a software package to accommodate the nonlinear interaction of the chemical species, which meshes satisfactorily with the dispersion scheme.

c. Extension of the model to 3-D by a "layer" approach for the vertical direction.

d. Applications of the model to realistic conditions requiring objective meteorological analyses and gridded emissions distributions serving as inputs to the model.

The pseudospectral method was chosen as the dispersion algorithm together with a variable grid spacing mesh. The latter was selected to encompass a large area in physical space as well as satisfy the periodicity requirements of the pseudospectral method. This method is highly recommended for simulations where numerical diffusion should be minimal, as is the case for the MAP3S model. Among the drawbacks of this method, of significance is the oscillatory nature of the dependent variable field, characteristic of methods employing finite Fourier series expansions. Since negative "concentrations" have no meaning and, indeed, threaten to complicate the chemical interaction simulations, it is recognized that acceptable means to alleviate this problem must be sought. It should be emphasized that all efforts in this area are geared toward placing the problem on a solid mathematical foundation and considerable research is devoted to problems of uniqueness of solution and stability.

The incorporation of nonlinear chemistry into the MAP3S model is envisioned in terms of a satisfactory decoupling of dispersion and chemical reaction. Since the equations describing the chemical reactions are largely quite "stiff," a Gear-type software package will be utilized. The inclusion of the various chemical species will be done gradually with painstaking attention to complicating interactions. It should be mentioned that the initial series of tests of Framework, including the case of "realistic" winds, will be performed with two species (SO_2 and $SO_4^{=}$) and linear chemistry.

The use of realistic wind fields as inputs to the model will be attempted with objective meteorological analyses. Existing methods will be reviewed and improved algorithms will be explored. At this stage, the mesh nonuniformity is perceived as a complicating factor. The gridding of the emissions distributions has been performed satisfactorily and will be employed in the initial testing simulations.

The structure of the Framework model was defined and the programming standards and conventions documented. An outline code was written with interim modules. The initial step has been the definition of the general computational flow of a time dependent air quality deposition model. Particular attention has been given to providing flexibility so that parameterizations of different types may be included. Internal data transfer (subroutine to subroutine) protocols have been developed by defining "labeled common" blocks of various types (e.g., meteorological data, chemical reaction rates, etc.); this is an area where a significant amount of iteration is required before one can reach final specifications as to dimensionality, units, etc.; hence, the current specification is considered subject to considerable modification. External data communication (e.g., wind data, gridded source emission data, etc.) has been provided for by defining an interim data file structure. To date rather rudimentary input/output has been provided; coupling to the various graphical output techniques will be done later.

The feasibility study of the pseudospectral method as the main dispersion code was completed. Considerable work was devoted to the testing of the central algorithm, the use of the Fast Fourier Transform (FFT), particularly vis-a-vis the variable grid spacing mesh. Figure 15 shows an example of the expanding grid superimposed upon a map of the eastern United States. A variety of test cases, in both 1-D and 2-D, were investigated. It was discovered that a considerable improvement in accuracy was achieved if certain operations were performed in spectral, rather than physical, space. Moreover, this improvement obviated the need for filtering (control of the high frequency components) which represents a drawback of the pseudospectral method. Some effort was devoted to the optimization of the routine algorithms of the code with an eye toward the full-scale calculations and the inherent limitations in computer storage and speed. An in-depth study of various time-integration schemes confirmed the original choice of "leap-frog" as the time-stepping algorithm.

As part of the MAP3S interlaboratory model comparison, monthly average SO_2 and SO_4 concentrations and deposition were calculated using the trajectory transport model, AIRSOX. The simulation period was July 1978 and the domain of the model was the U.S. east of the Mississippi River and the adjoining Canadian area. Comparison was made with SURE and MAP3S monitoring data. The smoothly varying observed SO_4 spatial pattern was also evidenced in the calculation except for areas of underprediction in the southern and western portions of the area modeled. SO_2 predictions showed less agreement with observations than did SO_4, particularly at the high and low concentration extremes. The accuracy of the wet deposition calculation was difficult to assess because of the limited number of observations.

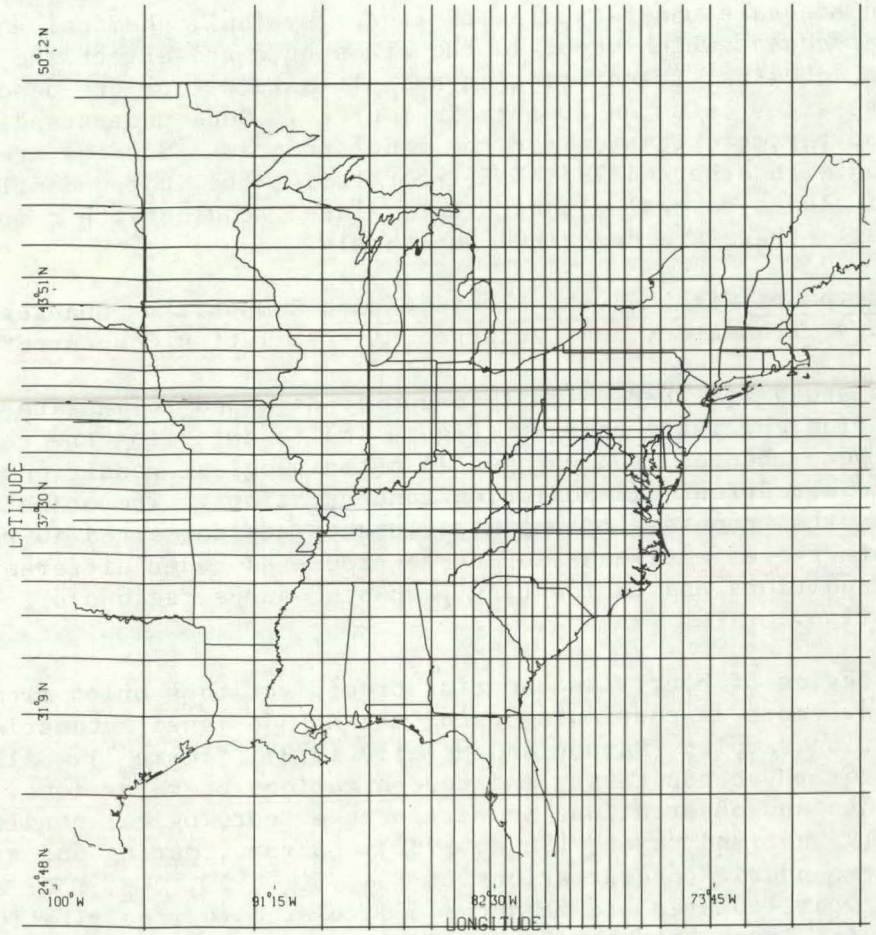

Figure 15. The expanding grid used in the Framework model superimposed on a map of the eastern United States.

Title: MAP3S/RAINE Field and Laboratory Studies

FY 81: $416,000**

FY 82: $390,000**

Principal Investigators:
Gilbert S. Raynor
Roger L. Tanner*
Sponsor: Office of Research and Development, EPA

The overall objective of the field and laboratory study programs is to obtain an adequate understanding of those physical, chemical and meteorological processes which occur in the atmosphere and affect the transport, diffusion, chemical transformation and ultimate wet or dry deposition of pollutants after emission from their sources. Such understanding is needed to develop parameterization for the model program. Studies are done in collaboration with other MAP3S/RAINE laboratories and independently. The BNL program includes several separate but related studies with complementary objectives. These are described separately.

Relationships of Within-Event Precipitation Composition Changes to Meteorology, Trajectory and Concurrent Air Pollution Concentrations

This study was started in 1976 and is designed to measure within-event precipitation chemistry changes (Figure 16) to determine the relationship between these changes, and changes in meteorological conditions, air trajectories and concurrent air pollution concentrations. The objectives are to understand the processes by which pollutants are deposited in precipitation, to evaluate the effectiveness of these processes under different meteorological conditions and to identify probable source regions of pollutants in precipitation.

Collection of hourly, sequential precipitation samples from all precipitation events is continuing using the BNL-designed automatic sequential precipitation sampler (Raynor and McNeil, 1979) (Figure 2). All samples are analyzed for pH, conductivity and concentrations of major ions. Concurrent measurements and observations of pertinent meteorological conditions are recorded (Raynor and Hayes, 1981a, 1982). Before, during and after selected events, atmospheric concentrations of SO_2, $SO_4^=$, NO, NO_2, HNO_3 and light scattering particulates are measured and related to precipitation composition. Mixing layer height before and after precipitation can be measured with an acoustic sounder or determined from NWS radiosonde data. Trajectory analysis for selected events are being performed using the Heffter Interactive-Terminal Transport model (Raynor and Hayes, 1981b). Detailed synoptic studies are being made of these events.

All precipitation events during FY 81 have been sampled on a sequential basis and chemical analysis of all samples is up to date. All meteorological data for each sample are entered in a computer data base with the

*Environmental Chemistry Division.
**Participation by the Environmental Chemistry Division to the extent of approximately one third of this budget.

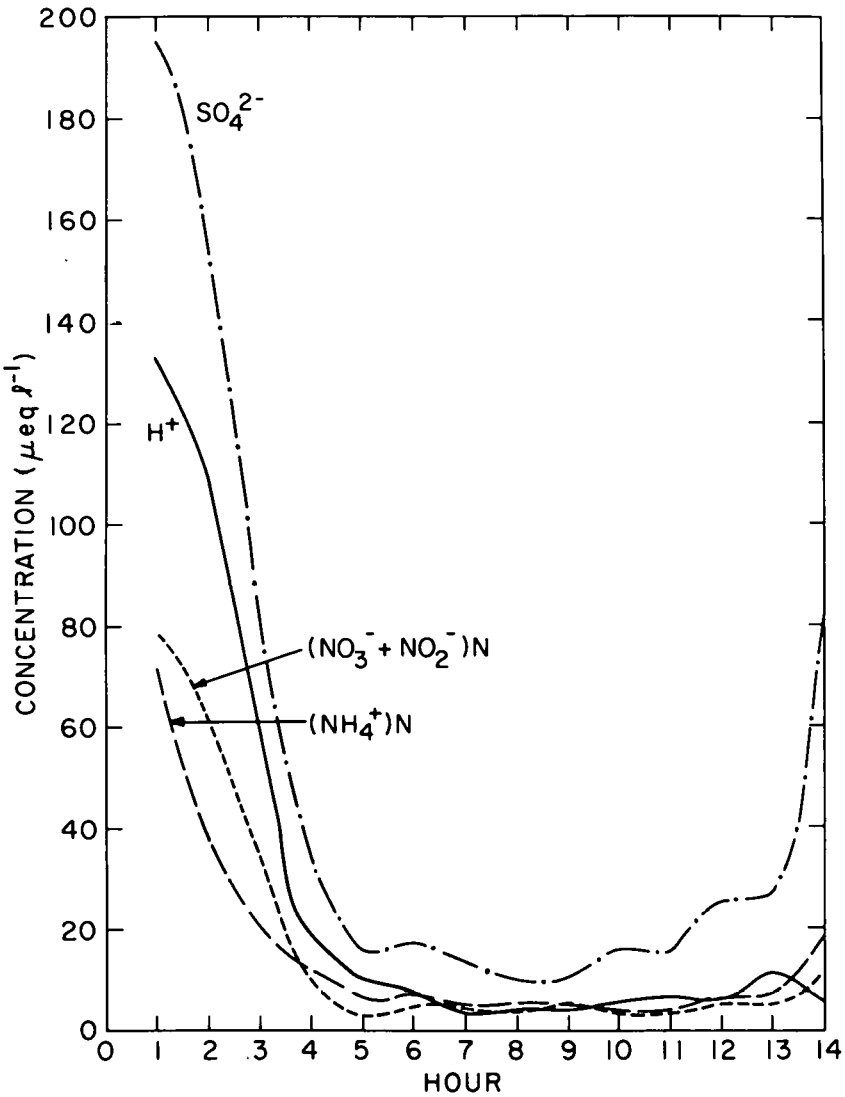

Figure 16. Change in concentration with time for four chemical species in hourly sequential precipitation samples during one rain event.

precipitation chemistry data. Several analytical studies have been conducted using the sequential data and have been or will be published. The ARL-ATAD trajectory model modified for interactive use on the BNL computer is being used to compute back trajectories from BNL and other MAP3S sampling sites during precipitation events to identify probable source regions (Figure 17). Air chemistry measurements were taken at BNL during the OSCAR experiment and will be related to precipitation chemistry. An acoustic sounder has been installed at BNL and is available for measuring the height of the mixing layer prior to precipitation events.

Measurements taken at the 37 Intermediate Density Precipitation Sampling Network stations during the April 1981 OSCAR experiment will contribute to this study and will be analyzed in relation to meteorological conditions and air trajectories. The BNL sequential data will also be related to air, cloud and rainwater chemistry measurements to be taken aloft during the in-cloud chemistry studies.

BNL also serves as a station in the MAP3S Precipitation Chemistry Network. A HASL-type sampler is used to take event samples which are sent to PNL for chemical analyses.

Effects of Urban Sources on Regional Deposition Chemistry

This study is designed to evaluate the effects of a major urban source on precipitation chemistry, to investigate the relative contributions of rainout and washout to total wet deposition and to determine the distance downwind to which an urban source contributes a significant percentage of the material deposited in precipitation. The New York metropolitan area will be used as a major urban source. Several event-type precipitation samplers will be operated during selected precipitation events at selected distances and directions from the source. These will be supplemented with mobile sampling teams using manually operated samplers. Locations will be selected so that measurements will be obtained at one or more upwind locations and two or more downwind distances. One mobile station has been instrumented with equipment for atmospheric chemistry measurements and will be used at selected locations. When conditions permit atmospheric chemistry and cloud water chemistry measurements will be made from the BNL aircraft above and in the urban plume at several distances. Differences in upwind and downwind precipitation chemistry will be related to source emissions, atmospheric chemistry and meteorological conditions to determine the influence of the urban source on precipitation composition. Cloud water and rainwater chemistry aloft will be compared to rainwater chemistry at the ground to evaluate washout efficiency and the relative importance of rainout and washout as a function of type and concentration of pollutants, rainfall type and rate, distance from the source and meteorological conditions.

During FY 81, a number of HASL-type event precipitation samplers were obtained. The large number of manually operated samplers built for the OSCAR experiment can also be used in this project. A mobile van was equipped with precipitation and atmospheric chemistry instrumentation. The BNL Islander aircraft has been equipped with cloud water collectors which will collect rain water as well. Event samplers have not yet been installed

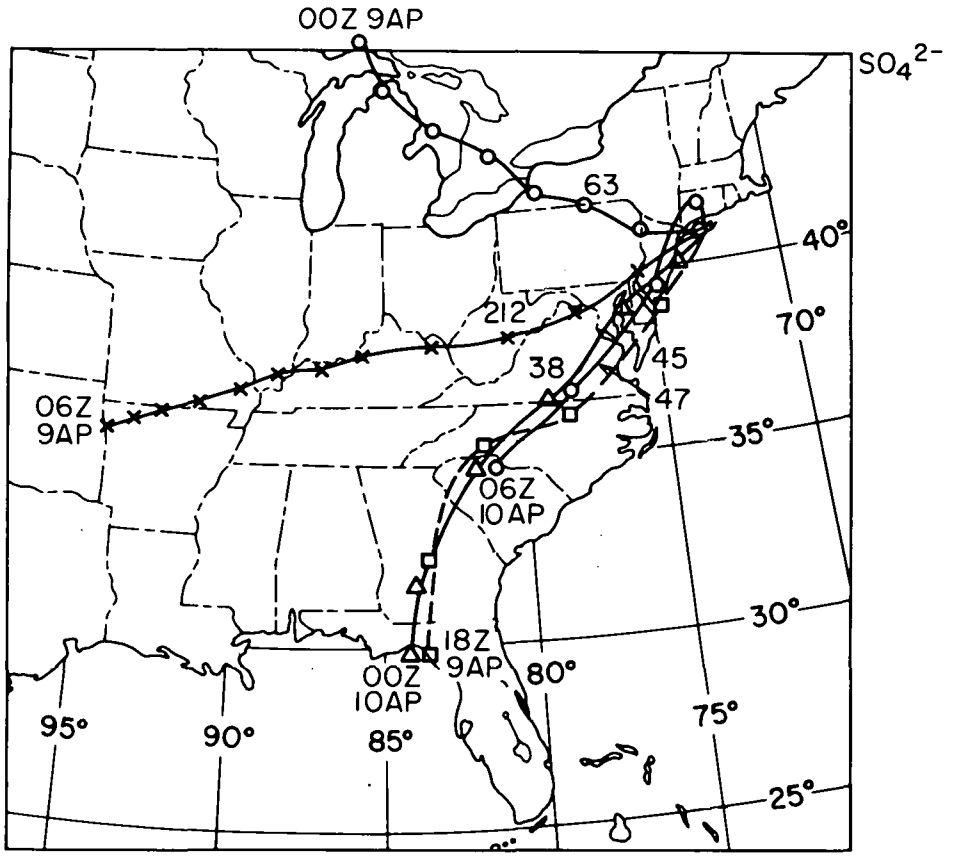

Figure 17. Trajectories ending at BNL at indicated times and dates with sulfate concentrations in precipitation for six hour periods centered on trajectory ending times beside each trajectory. The trajectory from the Ohio River Valley gave highest concentrations.

at other sites but some of the data obtained during the OSCAR experiment will partially fulfill the objectives of this project since sampling stations were located in various directions from the New York metropolitan area. Due to the success of the Intermediate Density OSCAR experiment, temporary manually operated stations may be used in selected precipitation events instead of fixed event samplers.

Equilibrium Effects on Precipitation Scavenging of Aerosols and Gases

The purpose of the equilibrium effects program is to use recently developed real time or short duration analytical techniques to measure all pertinent components in the aerosol sulfate, nitrate-gaseous ammonia, nitric acid system. These data are then compared with calculated concentrations based on phase equilibria considerations adjusted to the ambient conditions. Agreement between measured and calculated concentrations, especially for ammonia and nitric acid, under all or a subset of meteorological conditions at ground level or aloft should lead to more simplified modeling of scavenging processes leading to ionic deposition.

A measurement program with the overall goal of testing gas-aerosol phase equilibrium assumptions in the ambient atmosphere has begun and several experiments at ground level in non-precipitating atmospheres have been conducted. Recently, as part of the Oxidation and Scavenging Characteristics of April Rains (OSCAR) experiment, additional ground level experiments during frontal rains were also done. These will be followed in the next few months by clear-air experiments conducted from an aircraft platform as the required instrumentation package is completed and tested. Airborne measurements in precipitation at selected heights up through the cloud level(s) are then necessary to determine the dynamics of washout and rainout processes through characterization of the vertical profiles of gaseous, aerosol, and rain droplet concentrations. The data from experiments at this stage should establish if phase equilibria simplifications are appropriate for modeling of aerosol and gaseous wet deposition processes.

Continuous measurements of nitrogen oxides, sulfur dioxide, ammonia (Abbas and Tanner, 1981), aerosol sulfur (D'Ottavio et al., 1981), and water vapor have been made in experiments to date, supplemented by continuous measurements of ozone, light scattering, hydrocarbons, wind speed and direction, temperature and relative humidity. Essential filter measurements of aerosol acid, ammonium, and sulfate, and of SO_2 were made with the BNL filter pack. Nitric acid and particulate nitrate were measured by the diffusion denuder method. Newly modified techniques for continuous SO_2, aerosol sulfate, nitric acid and ammonia measurements from the aircraft are now available for future airborne experiments.

Analysis of data accumulated in the first three clear air experiments conducted in 11/79 (BNL), 2/80 (BNL) and 8/80 (Baltimore, MD) was completed in FY 1981. Results (Tanner, 1981a, 1981b) suggest that during a daytime period with aerosol composition approximating a letovicite-NH_4NO_3 mixture, observed levels of $NH_3(g)$ and $HNO_3(g)$ agreed with those calculated from the ammonium nitrate-$NH_3(g)$, $HNO_3(g)$ equilibrium. Thus this equilibrium appears

to respond dynamically to changes in either gaseous or aerosol concentrations in the ambient atmosphere. Surface level concentrations of ammonia, however, appear to be higher than predicted for measured acid sulfate aerosol concentrations; known error sources in observed and calculated concentrations do not yet provide a satisfactory explanation.

Three phase equilibrium experiments were conducted in FY81. The first was an abbreviated clear air experiment at BNL in March, 1981 done under snow-cover near $0^{o}C$ conditions. The latter two were done during precipitation events as part of the OSCAR experiment using an instrumented van located near Ft. Wayne, IN. Data from these experiments is still being accumulated, but it may be noted that during the OSCAR experiments, a modified, high-sensitivity ozone-chemiluminescence technique was successfully used to continuously measure nitric acid as well as NO_x; measured levels were equal to or lower than those observed by the previously used denuder technique.

Cloud Processing Studies

The objective of the cloud processing studies is to understand the role of clouds in the transformation and relocation of pollutants so that the mechanisms by which pollutants are produced or scavenged by clouds and removed from the atmosphere can be modeled.

These studies are designed to do experimental measurements from an aircraft to determine vertical profiles of important ionic species and their gaseous precursors through cloud layers. Air chemistry measurements will be made above, below and in the cloud layer. Cloud water will be collected from the cloud layer for subsequent chemical analysis. Concurrent measurement of cloud liquid water content and if possible droplet size distribution will be made.

From these measurements, identification of those precursors for which cloud processing is important will be attempted. If vertical velocity measurements can be made, the data will be analyzed to determine the fraction of pollutants entering the cloud that are incorporated into the cloud droplets and to document temporal changes in cloud water composition. Results will be related in a qualitative way to the type and concentration of materials in the entrained air, the vertical air velocities, and the cloud water concentrations.

The BNL aircraft has been equipped with much of the instrumentation required for these experiments. An ASRC (Atmospheric Sciences Research Center, State University of New York at Albany) airborne cloud water collector and a CT (Cloud Technology, Palo Alto, CA) liquid water content indicator have been installed and tested, and have been found to operate sufficiently well for the purposes of these experiments. A flow stabilized flame photometric instrument for gaseous and aerosol sulfur measurements has been constructed and tested, and work is now proceeding on developing a doped hydrogen system to enhance the sensitivity so that background levels of SO_2 and aerosol sulfur can be measured. The second model of a supersensitive instrument for continuously measuring sub-ppb levels of NO_x and $NO_x + HNO_3$ is also being constructed, and will be tested in the near future.

Some preliminary scoping measurements have been made to collect cloud water samples for chemical analysis, and to establish the feasibility of our scientific approach.

OSCAR Experiment

The interlaboratory MAP3S/RAINE OSCAR (oxidation and scavenging characteristics of April rains) study was designed to provide a detailed examination of the dynamics and chemical features of selected frontal systems in the eastern U.S., to assess the spatial and temporal variability of precipitation chemistry, to provide a data base for model development, to develop increased understanding of wet removal mechanisms and to identify source areas.

The OSCAR study included two concurrent components, a High Density Network and an Intermediate Density Network (Raynor, 1981) (Figure 18). The latter was planned and operated by BNL. A network of 37 stations was established in the northeastern U.S. to sample up to four rain events with fine temporal and moderate spatial resolution. Manually operated funnel and jar collectors were used to sample each 0.6 mm of rain throughout each event. A forecast center at BNL advised station operators of expected beginning and ending times and directed activities of the BNL aircraft which took atmospheric chemistry measurements in support of the study. Ground-level air chemistry measurements were made at BNL and at Fort Wayne, Indiana. Field pH measurements were taken at each site. Complete chemical analyses are being made at PNL.

References

Abbas, R. and R.L. Tanner, 1981: Continuous determination of gaseous ammonia in the ambient atmosphere using fluorescence derivatization. Atmos. Environ. 15: 277-281.

D'Ottavio, T., R. Garber, R.L. Tanner and L. Newman, 1981: Determination of ambient aerosol sulfur using a continuous flame photometric detection system. II. The measurement of low-level sulfur concentrations under varying atmospheric conditions. Atmos. Environ. 15: 197-203.

Raynor, G.S. and J.P. McNeil, 1979: An automatic, sequential precipitation sampler. Atmos. Environ. 13: 149-155.

Raynor, G.S., 1981: Design and preliminary results of the Intermediate Density Precipitation Chemistry Experiment. To be presented at and printed in preprint volume of AMS/APCA 3rd Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. Report BNL 29992.

Raynor, G.S. and J.V. Hayes, 1981a: Acidity and conductivity of precipitation in central Long Island, New York in relation to meteorological variables. Water, Air and Soil Pollution 15: 229-245.

Raynor, G.S. and J.V. Hayes, 1981b: Effects of varying air trajectories on spatial and temporal precipitation chemistry patterns. Water, Air and Soil Pollution (in press).

Raynor, G.S. and J.V. Hayes, 1982: Concentrations of some ionic species in central Long Island, New York precipitation in relation to meteorological variables. Water, Air and Soil Pollution (in press).

Tanner, R.L., 1981a: An ambient experimental study of phase equilibrium in the atmospheric system: Aerosol H^+, NH_4^+, SO_4^{2-}, NO_3^---$NH_3(g)$, $HNO_3(g)$. Atmospheric Environment (submitted); BNL 30159.

Tanner, R.L., 1981b: Phase equilibrium in the mixed aerosol-gaseous ammonia, nitric acid system--relevance to considerations of ion incorporation into rainfall. Presented at the 182nd National Meeting, American Chemical Society, New York, NY, August 23-28, BNL 29994.

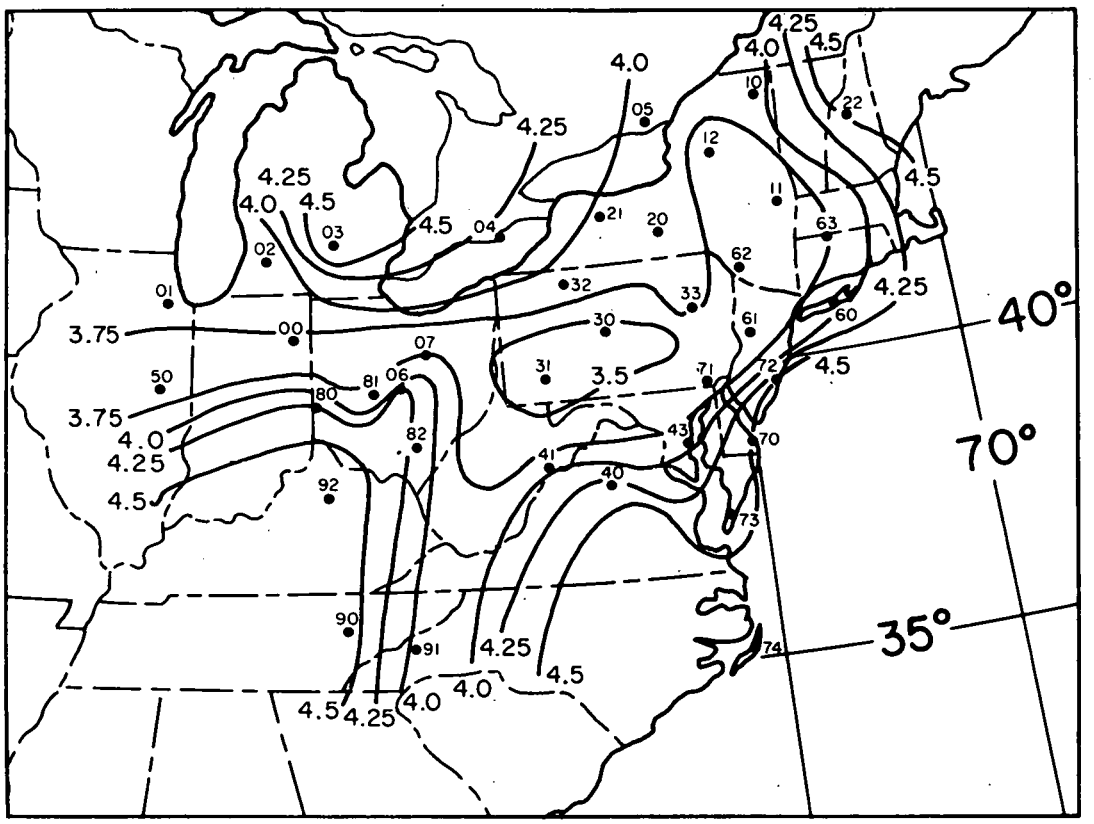

Figure 18. Isopleths of pH measured in the first sample taken at each station during the rain event of April 22-24, 1981 superimposed on a map showing the locations and numbers of the 37 Intermediate Density Network sampling stations.

Title: MAP3S/RAINE Central Data Coordination

FY 81: $173,000

FY 82: $188,000

Principal Investigator: Carmen M. Benkovitz

Sponsor: Office of Research and Development, EPA

The Central Data Coordination task of the MAP3S/RAINE program collects, integrates and disseminates the appropriate experimental data generated by the MAP3S and collaborating programs and the auxiliary data needed by MAP3S program participants. Merging of disparate data into working data sets as required by MAP3S research activities is accomplished once and allows researchers to access the same information from one central location. The following outlines some of the activities of the MAP3S Central Data Coordination function.

A source emissions inventory has been compiled for anthropogenic emissions of the five criteria pollutants (particulates, SO_x, NO_x, hydrocarbons and CO) covering the United States and Canada (Benkovitz, 1980, 1981a, 1981b,; Benkovitz and Evans, 1981). Methodologies are being developed to allow the conversion of these emissions data into formats suitable for input to mathematical models of air quality.

Air quality data generated by the ground station network of the Sulfate Regional Experiment (SURE) are available for analysis and has been used for model intercomparison (Shannon et al., 1981). This fifty-two station network covering the north and middle eastern United States was operated between August 1977 and December 1978. Additional air quality data can be obtained from the National Aerometric Data Bank (NADB) of the Environmental Protection Agency (EPA).

Precipitation chemistry data generated by the nine-station network operated by the MAP3S program are also available. Additional data generated by precipitation chemistry networks operated by the Electric Power Research Institute (EPRI), the National Atmospheric Deposition Program (NADP) and the Canadian Network for Sampling Precipitation (CANSAP) is in the process of being acquired.

Data coordination for the Oxidizing and Scavanging Characteristics of April Rains (OSCAR) experiment is underway. The auxiliary data needed for the experimental period was compiled and used; data generated by the experiment and auxiliary data needed for post-experiment analyses are being gathered.

The Heffter Interactive-Terminal Transport Model (HITTM), a regional scale trajectory transport model, has been installed at the Central Scientific Computing Facility and is available for interactive use by all interested parties (Benkovitz and Heffter, 1980). The associated meteorological data base is maintained starting from January 1, 1977.

References

Benkovitz, C.M. and J.L. Heffter, 1980: User's guide to the Heffter Interactive-Terminal Transport Model (ARL-HITTM). BNL 27801.

Benkovitz, C.M. and V.A. Evans, 1981: User access to the MAP3S source emissions inventory. BNL 29322.

Benkovitz, C.M., 1980: MAP3S/RAINE emissions inventory progress report. BNL 51378.

Benkovitz, C.M., 1981a: Compilation of an inventory of anthropogenic emissions in the United States and Canada. Accepted for publication in Atmos. Environ.

Benkovitz, C.M., 1981b. Compilation of source emissions data and their use in air quality models. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 1982.

Shannon, J.D., L. Kleinman, C. Benkovitz, and C. Berkowitz, 1981: Intercomparison of MAP3S models of long-range transport and deposition. To be presented at and printed in preprint volume of AMS/APCA 3rd Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982.

Title: Planetary Boundary Layer Studies at Land-Sea Interfaces

FY 81: $250,000

FY 82: $250,000

Principal Investigators:
Gilbert S. Raynor
S. SethuRaman
Sponsor: Office of Health and Environmental Research, DOE

The primary purpose of this program which began in 1972 is to obtain an understanding of those meteorological processes that occur in or are unique to coastal zones and that affect the siting, operation, or safety of power plants or other energy-related facilities or activities in coastal areas. A further purpose is to develop and test an operational predictive capability for application to coastal sites and processes. This predictive capability would include a reliable system for describing diffusion conditions affecting airborne effluent releases from coastal or offshore sites and for predicting resultant concentration or dosage patterns. The methods would be based on such measurable meteorological and surface parameters as synoptic situation, type of flow (gradient or sea breeze), wind and temperature structure over water and over land, sea-surface and land-surface conditions, and coastal terrain. Developing this capability requires an understanding of air-sea interaction processes and of meteorological processes in transition regions where air is modified as it flows from land to water or water to land. An additional purpose is to develop a rating system for potential plant or activity sites based on onshore wind frequency, diffusive capacity, and severe weather prevalence. A final purpose is to obtain a data set and analytical methods for predicting weather effects on any energy production, transmission, or utilization activity in coastal areas.

Among the major accomplishments of the program was the documentation on a systematic basis of diffusion rates over the water and at the coast as a function of meteorological and surface conditions. Experiments demonstrated that diffusion could be much less under stable conditions over water than predicted by any commonly used method for calculating diffusion over land (Raynor et al., 1975). More recent experiments, for the first time, used SF_6 tracer gas and an array of radio-controlled remote sampling stations to measure diffusion in the transition region where overwater flow is gradually modified by passage over land.

By means of simultaneous diffusion experiments from a small island and a nearly oceanic site (Raynor et al., 1978), it was demonstrated that wake effects about a major obstacle to free air flow could be minimal during stable conditions. This raised doubts about the validity of NRC regulations which allow credit in diffusion calculations for added spread due to wake effects about nuclear power plants in coastal zones.

A major effort in the program is an investigation of coastal internal boundary layers which form whenever air flows from a smooth and usually colder water surface to a rougher and usually warmer land surface (Figure 19). Coastal boundary layer development is being studied in a series of experiments using two aircraft for measurements aloft and such ground-based

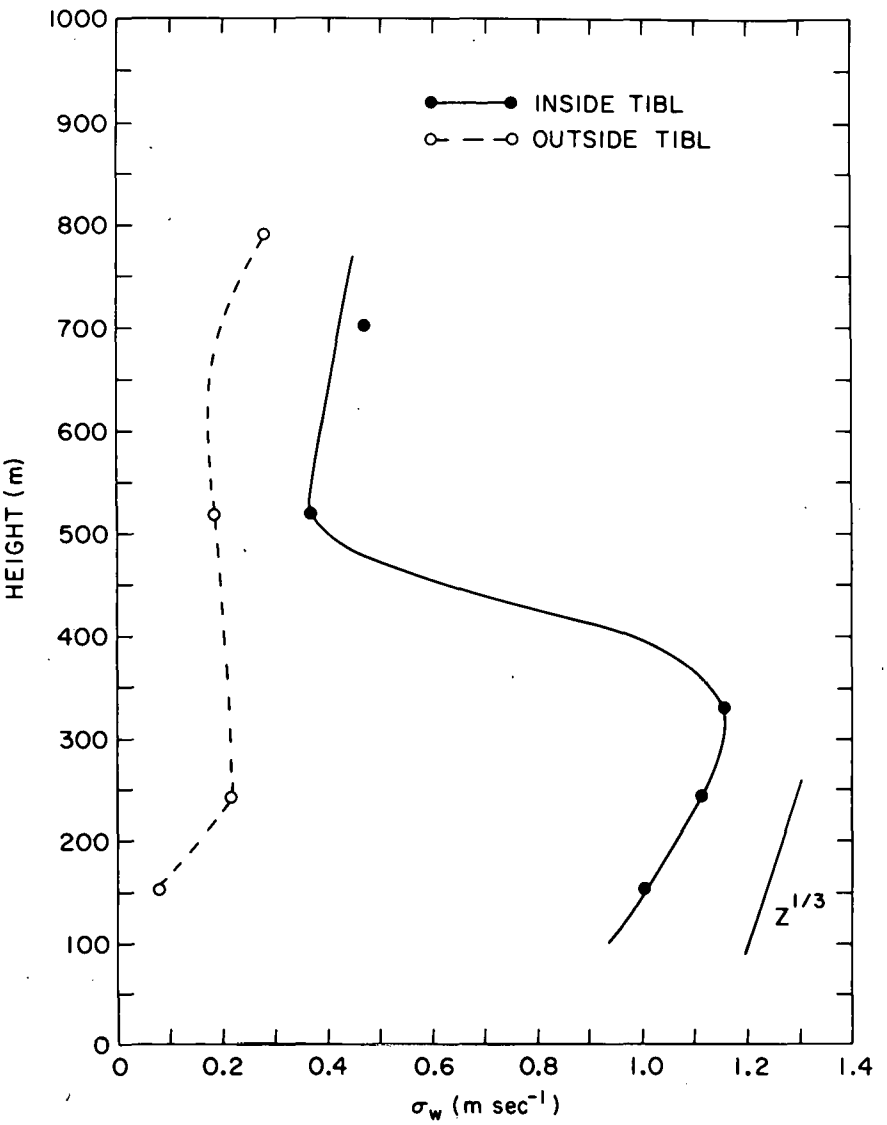

Figure 19. Variation of the standard deviation of vertical velocity fluctuations (σ_w) in and outside of the thermal internal boundary layer over Long Island for a case where a sea breeze was present. Winds were southwesterly and a strong surface-based inversion was present over the ocean.

aids as pilot balloon soundings, an acoustic sounder and a tethersonde in which data from a sensor package on a tethered balloon is radioed to a ground-based receiver. This program led to the development of a mathematical model for predicting the height of the coastal internal boundary layer as a function of meteorological and surface conditions. Early results of these studies were presented by Raynor et al. (1979b).

Another important part of the program was the study of marine meteorology and atmosphere-ocean interactions using an air-sea interaction buoy designed and built at BNL (Huszagh et al., 1979). Several experiments were conducted with this buoy moored in the Atlantic Ocean off Long Island (SethuRaman et al., 1978). Existence of internal gravity waves over the water at heights less than 25 m was found for the first time and the energy dissipation and increased diffusion due to their breaking was documented (SethuRaman, 1977, 1980) (Figure 20). Pioneering work on the mechanism of momentum transfer to the ocean due to different stages in wave development was also done through successive experiments (SethuRaman and Raynor, 1975). The structure of turbulence over oceans during high winds was studied and was found to be markedly different from that generally assumed (SethuRaman, 1979). Scales of turbulence over water were also found different from over-land values. Surface waves were found to play an important role in the generation of atmospheric turbulence in the lowest 100 m. Comparison studies of the characteristics of the winds offshore with the values at the beach were made to understand the variations for onshore and offshore flows (SethuRaman and Raynor, 1980) which has applications to the siting of wind energy facilities.

The program also led to a series of important instrumental developments including the adaptation of a sailplane variometer to measure turbulence from a light aircraft, the development of a new fast-response but rugged bivane, the design of the radio-controlled remote sampling system mentioned above and the development of a satellite telemetry system for transmitting real time turbulence and flux data from a buoy or other remote location (Lobecker et al., 1980) (Figure 11).

Other developments included an air-sea interaction observation system that can be used in remote locations for long time periods. A completely mobile atmospheric boundary layer system has also been developed and was used in remote locations (SethuRaman et al., 1980) during two international experiments.

Another important accomplishment was a study of the transport and diffusion climatology of the U. S. Atlantic and Gulf coasts (Raynor and Hayes, 1981). This study was designed to aid in site selection and in evaluation of existing sites in terms of diffusion conditions. It is the first comprehensive diffusion climatology produced for this purpose. A study of NRC regulations for measurement programs and diffusion modeling methods for use at nuclear reactor sites was made to determine their adequacy for plants in coastal locations. This study was based on experience and data gained in the coastal program and on an extensive literature survey and resulted in a series of recommendations for changes in procedures (Raynor et al., 1979a, 1980).

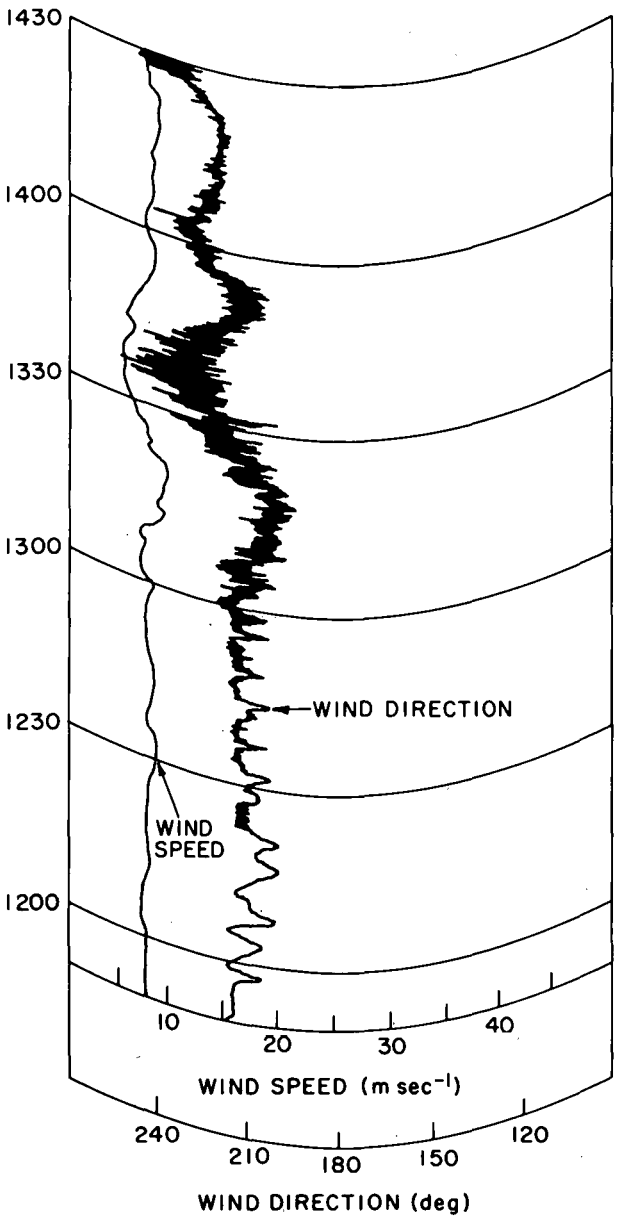

Figure 20. Trace of wind speed and direction at a height of 24 m at Tiana Beach. Formation of internal gravity waves is shown by the wave-like direction changes and their breaking by periods of increased turbulence.

During FY 81, several combined oil-fog smoke and SF_6 diffusion tests were conducted to determine diffusion rates in the transition zone. The development of the internal boundary layer during offshore flow was studied over the ocean using instruments carried aloft by a tethersonde and by the BNL aircraft. A study of changes in wind direction and speed during inland flow was made using data previously collected at BNL, Brookhaven Airport, and Smith's Point. Results show a large decrease in wind speed and a turning in direction with distance inland. A study of the frequency and magnitude of wind direction meander during onshore flows was started. A long period of high quality wind, turbulence and temperature data were obtained from instruments on the Tiana and Hampton Bays towers and is being analyzed to quantify the differences in turbulence and other parameters between overwater and overland flows. During the summer of 1981, some personnel and equipment were used in the API-SRI experiment in the Gulf of Mexico as described elsewhere.

References

Huszagh, D., W. Ripperger and S. Fink, 1979: Design, construction, and initial operation of the BNL coastal transport and diffusion air/sea interaction research buoy. BNL 51111.

Lobecker, R.N., S. SethuRaman and G. Field, 1980: SATDAS for air-sea interaction data acquisition using satellite telemetry. Bull. Amer. Meteor. Soc. 61: 1212-1222.

Raynor, G.S., P. Michael, R.M. Brown and S. SethuRaman, 1975: Studies of atmospheric diffusion from a nearshore oceanic site. J. Appl. Meteor. 14: 1080-1094.

Raynor, G.S., R.M. Brown and S. SethuRaman, 1978: A comparison of diffusion from a small island and an undisturbed ocean site. J. Appl. Meteor. 17: 129-139.

Raynor, G.S., P. Michael and S. SethuRaman, 1979a: Recommendations for meteorological measurement programs and atmospheric diffusion prediction methods for use at coastal nuclear reactor sites. BNL-NUREG-51045, NUREG/CR-0936.

Raynor, G.S., S. SethuRaman, and R.M. Brown, 1979b: Formation and characteristics of coastal internal boundary layers during onshore flows. Boundary Layer Meteor. 16: 487-514.

Raynor, G.S., P. Michael and S. SethuRaman, 1980: Meteorological measurement methods and diffusion models for use at coastal nuclear reactor sites. Nuclear Safety 21: 749-765.

Raynor, G.S. and J.V. Hayes, 1981: Climatology of transport and diffusion conditions along the United States Atlantic and Gulf coasts. J. Appl. Meteor. 20: 882-889.

SethuRaman, S. and G.S. Raynor, 1975: Surface drag coefficient dependence on the aerodynamic roughness of the sea. J. Geophys. Res. 80: 4983-4988.

SethuRaman, S., 1977: The observed generation and breaking of atmospheric internal gravity waves over ocean. Boundary-Layer Meteor. 12: 331-349.

SethuRaman, S., W.A. Tuthill and J. McNeil, 1978: Instrumentation and data acquisition system for an air-sea interaction buoy. Bull. Amer. Meteor. Soc. 59: 1102-1112.

SethuRaman, S., 1979: Structure of turbulence over water during high winds. J. Appl. Meteor. 18: 324-328.

SethuRaman, S., 1980: A case of persistent breaking of internal gravity waves in the atmospheric surface layer over the ocean. Boundary Layer Meteor. 19: 67-80.

SethuRaman, S., P. Michael, W.A. Tuthill and J. McNeil, 1980: An observation system used to study the marine boundary layer over the Bay of Bengal during summer MONEX 79. Amer. Meteor. Soc. 61: 1204-1211.

SethuRaman, S. and G.S. Raynor, 1980: Comparison of mean wind speeds and turbulence at a coastal site and offshore location. J. Appl. Meteor. 19: 15-21.

Title: Interregional Air Quality

FY 81: $105,000

FY 82: $ 50,000

Principal Investigator: Lawrence I. Kleinman

Sponsor: Office of Environmental Assessment, DOE

The aim of the interregional air quality program is to develop and use the analytic and computational tools necessary to analyze the environmental consequences of our present and planned energy related policies. The environmental consequences that are of particular interest are those occurring on a regional scale, typified by pollutant long range transport and acid deposition. The Office of Environmental Assessment of the Department of Energy (DOE) is interested in determining the impacts in these areas due to air quality regulations and shifts in energy utilization patterns. Such shifts might, for example, arise from economic, demographic, or regulatory changes. Predicted air quality and deposition changes are interpreted at DOE from the standpoint of whether they pose constraints on energy utilization.

Two categories of activities are included in the interregional air quality program; those related to assessments of particular scenarios and those related to the more generic task of methodology development. Many problems are worked on in cooperation with the Energy and Economic Analysis Division at BNL.

Assessments in the past have involved determining a range of impacts (air quality, water quality, waste disposal, economic, etc.) of future scenarios for economic growth and energy utilization. Participants from several national laboratories have worked together on programs to evaluate the impacts of increased coal utilization (Meyers et al., 1979), increased solar energy deployment (Lipfert and Kleinman, 1981), and the President's National Energy Plan (Kleinman et al., 1979). For these programs the Atmospheric Sciences Division has used the AIRSOX long range transport model to calculate the air and deposition impacts of the sulfur oxides.

Methodology development tasks in support of these programs have included the generation of transfer matrices for SO_2 and SO_4 air quality and deposition. Each element of these matrices gives the impact of a unit emission source in a specified emitter Air Quality Control Region (AQCR) upon the air quality or deposition in a specified receptor AQCR. For example, if the transfer matrix for SO_4 air quality is multiplied by a vector consisting of emission source strengths, the resulting vector is a list of SO_4 concentrations in each AQCR due to the combined effects of all sources. These matrices are currently being used at DOE for quick turnaround impact studies, processing of multiple emission scenarios and analytic explanation of generic properties of transport.

In FY 81 most of our efforts were devoted to two problems: 1) the writing of an information book on the nitrogen oxides, titled "NO_x

Information Book" (USDOE, 1981) and, 2) the calculation of the effect of stack height on air quality and deposition impacts of SO_2 and SO_4 (Kleinman, 1981).

The NO_x handbook is a multilaboratory effort commissioned by DOE for the purpose of providing policy maker with current information on the effects, properties, and sources of the nitrogen oxides and derived pollutants. The handbook is intended to be accessible to a reader with a technical background but without specific knowledge of the environmental topics covered. BNL contributed sections on sources, emissions, atmospheric transport, chemical transformation, deposition and ambient concentrations.

Questions concerning the relative impacts of varying stack height are prompted in part by our desire to understand long-term trends in air quality and acid deposition and in part by our need to predict the effectiveness of possible regulatory action limiting stack heights. Hypotheses have been advanced suggesting that the decrease in pH of rainfall and the constancy of SO_4 levels accompanied by decreasing SO_2 levels in urban areas are effects of a shift in emissions from short to tall stacks. The qualitative argument is that by increasing stack heights, primary pollutants (i.e., SO_2) are less susceptible to removal at the ground by dry deposition. An increase in atmospheric residence time results which allows for an increased time for oxidation to SO_4 to occur.

In order to quantitatively evaluate the difference in downwind impacts of tall and short stacks we have integrated a vertical diffusion equation which describes the dispersal, deposition and reaction of pollutants in the atmosphere following emission from a specified stack height. The calculations performed were in essence single source runs of the long-range transport model, AIRSOX, without pollutant advection. The integration proceeds for 96 hours, the emitted pollutant experiencing four repetitions of a diurnally varying planetary boundary layer (PBL) characteristic of a summer convective day with a nocturnal surface-based inversion. Results of integrating the diffusion equations are SO_2 and SO_4 concentrations as a function of altitude, emission time, travel time in the atmosphere and stack height.

It is found that most of the tall-short stack difference occurs from nighttime emissions when plumes from elevated sources are decoupled from the ground while low lying emissions are trapped by the nocturnal inversion. The differential in SO_4 forming ability is then dependent upon the rate at which dry deposition of SO_2 occurs at night. An indirect and qualitative determination of the nocturnal deposition rate is arrived at by considering the SO_2 diurnal cycle which reflects the time evolution of the coupling of an emission source with the ground. For this purpose, an observed diurnal cycle was calculated by averaging a month-long period of hourly monitoring data from the SURE network. Comparison is made with a calculated diurnal cycle assuming a homogeneous distribution of emission sources of different heights (Figure 21). Deposition velocities of SO_2 of the order of 0.5 cm/sec at night are indicated by this comparison. A source with a 400-m effective stack height is then calculated to produce approximately 40% more SO_4 than a 40-m source. At this point, however, alternate explanations for the diurnal cycle must be explored and the variability of the stack height effect with meteorological conditions assessed.

References

Kleinman, L.I., R.T. Cederwall, and R.E. Meyers, 1979: Modeling sulfur oxide concentrations: An assessment of energy utiliziation scenarios. Proceedings Sixth National Conf. on Energy and Environment, Pittsburgh, Pa., May 21-24, 1979, pp. 85-92.

Kleinman, L.I., 1981: The effect of stack height on SO_x impacts. Presented MAP3S/RAINE Biennial Review Meeting, Jekyll Island, Ga., November 16-19, 1981, BNL 30593.

Lipfert, F.W. and L.I. Kleinman, 1981: The influence of solar energy deployment in long-range transport air pollution. BNL 51350, July 1981.

Meyers, R.E., R.T. Cederwall, L.I. Kleinman, and S.E. Schwartz, 1979: Atmospheric production and transport of sulfur oxides in the United States. BNL 26371, May 1979.

U.S. Department of Energy, Office of Environmental Programs, Division of Environmental Policy, 1981: NO_x Information Book. Prepublication Draft, November 1981.

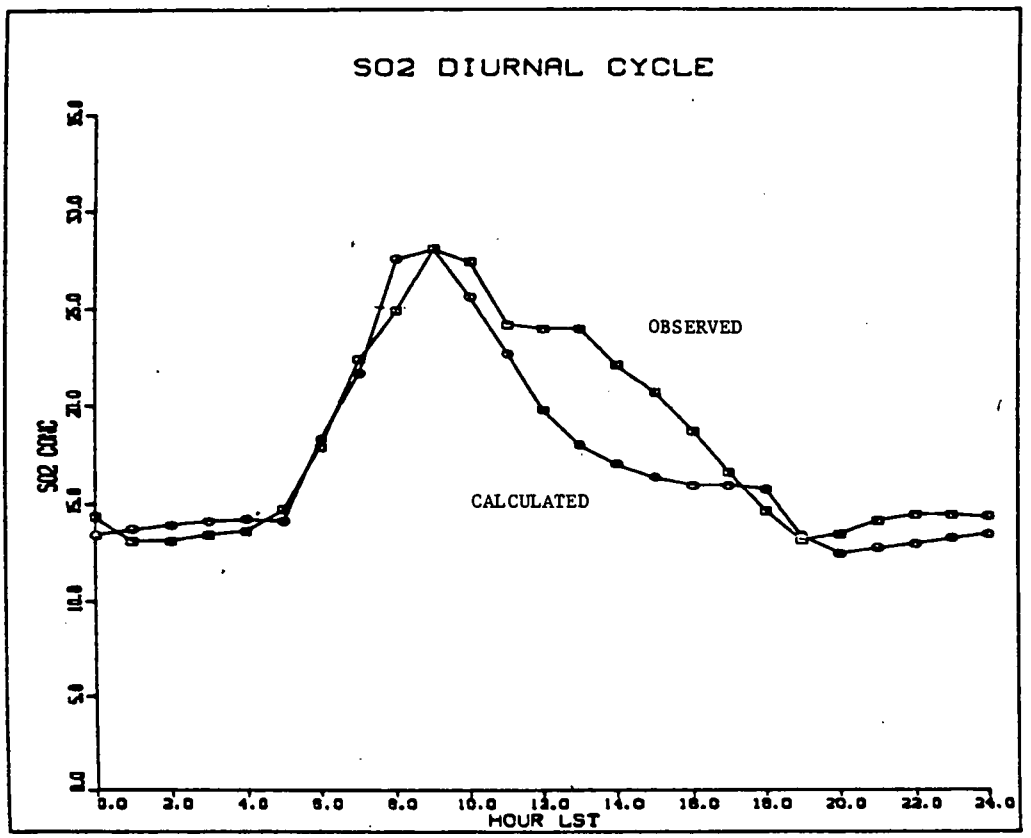

Figure 21. Comparison of calculated diurnal cycle for SO_2 concentrations with average measured SO_2 concentrations at 51 SURE stations during July 1978. The calculated curve is normalized to match the observed peak.

Title: Northeast Regional Oxidant Study (NEROS)

FY 81: $ 90,000**

FY 82: $ 81,000**

Principal Investigators:
Robert M. Brown, Peter H. Daum* and Joyce L. Tichler
Sponsor: Office of Research and Development, EPA

In order to assess overall strategies for oxidant control and recognizing the significance of the long-range transport of ozone and its precursors in the environment, EPA initiated a program to develop a regional scale photochemical air quality model. Two major field experiments have been conducted in order to provide data to evaluate, refine and verify the model. Brookhaven personnel particpated in both of these field experiments which were conducted in August of 1979 and July and August of 1980. The Brookhaven Islander aircraft and mobile van both stationed in the Baltimore-Washington region and both instrumented with air sampling instruments were operated by BNL personnel during the 1980 study. In 1981 further analysis of the data collected by BNL continued, culminating in the shipment to EPA of edited data tapes of the BNL aircraft and van missions and complete documentation of each mission in the form of a hardcopy data report.

---

*Environmental Chemistry Division.

**Participation by the Environmental Chemistry Division to the extent of approximately 50% of this budget in FY 81 and 20% in FY 82.

Title: METER Program Activities at BNL

FY 81: $ 57,000

FY 82: $ 60,000

Principal Investigator:
Aristides A. N. Patrinos
Sponsor: Advanced Nuclear Systems and Projects Division, DOE

The Meteorological Effects of Thermal Energy Releases (METER) Program addresses the inadvertent weather modification effects of power plants which employ cooling towers and cooling ponds. Funded by DOE since FY 76, the METER Program has addressed a variety of potential meteorological effects such as fog, icing, drift deposition, precipitation modification and others. The program has utilized all available research tools but has placed its emphasis on the acquisition of field data for model verification purposes. Since FY 78 activities of the METER Program have concentrated on a precipitation modification study at the Bowen Electric Generating Plant in northwestern Georgia. This 3200 MWe (electric) coal-fired power plant of the Georgia Power Company is among the largest in the U.S. and employs four natural draft cooling towers and two smokestacks. The study was undertaken by Oak Ridge National Laboratory (ORNL) and involved the installation and operation of a network of recording raingages and windsets on a square grid centered at the power plant. Data acqusition covered a period of three years (February 1978 to February 1981) and details and results of this study may be found in the reports and articles published on behalf of the METER Program (Patrinos and Hoffman, 1979; Patrinos et al., 1979; Patrinos and Bowman, 1980). Most efforts in this weather modification study concentrate on the use of nonparametric statistics for the delineation of possible effects with the use of a sophisticated statistical design. Results to date cover the first 18-month data acquisition period and it has been concluded that the effects of the power plant on local rainfall is marginal, at best, for the data stratifications considered. Preliminary results of the analyses on the entire 3-year data set indicate no significant change of the earlier conclusions. Some indication of a change in the storm pattern variability for stationary front storms has been discovered. This change may be attributed to the power plant and is being investigated further. The involvement of BNL in the METER Program started during FY 81 when one of the METER Program's principal investigators (A. Patrinos) joined the staff of the Atmospheric Sciences Division. A recent review article (Patrinos, 1981) described some of the statistical methods employed in the study. Figure 22 presents the precipitation amounts over the network for the first 18-month period.

A relatively late development in the METER program has been the WISPE field study (Winter Study of Power Plant Effects). This effort to examine wetfall chemistry in the Plant Bowen vicinity was seen as a logical extension of the ongoing rainfall modification study and as an opportunity not only to determine the magnitude of local wet deposition from the stack plumes but also to provide some information on the precipitation chemistry (levels and spatial variability) of the southeastern U.S. In a very real sense, the WISPE experiment aslo reflects an important attribute of the

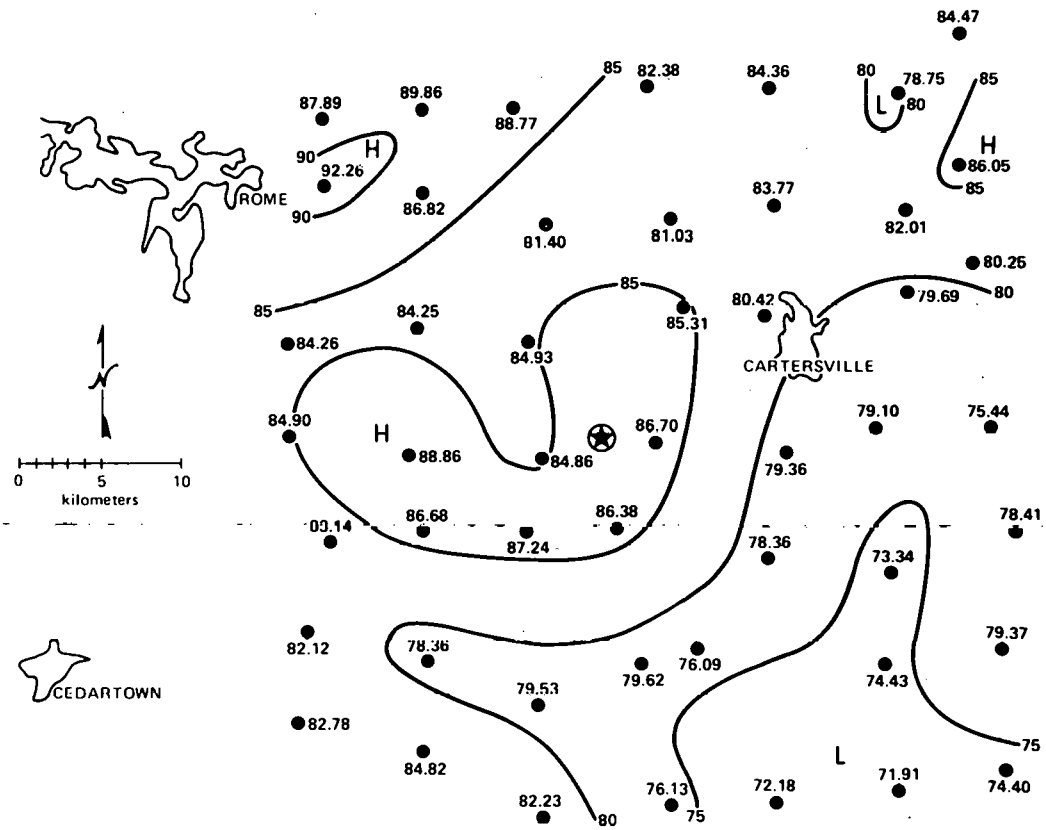

Figure 22. Precipitation amounts over the METER sampling network for the first 18-month period.

METER program, in that it has provided the structure for bringing together diverse capabilities in a coordinated field experiment. WISPE was designed as a two-season experiment. The first endeavor was undertaken in December 1979 and involved both airborne and ground-level measurements in a rather ambitious undertaking (Patrinos, 1980).

The second undertaking (WISPE-II) took place over a longer time period (January 12, 1981 to March 12, 1981) and concentrated entirely on the study of wetfall chemistry. A rather dense network of automatic wetfall collectors together with a supporting network of manually installed bulk collectors were employed during the two-month period. Extensive air chemistry measurements were made at two key sites of the network while an acoustic sounder in the power plant's vicinity enriched the routine meteorological data measurements of the precipitation modification study. A total of eleven precipitation events were sampled during WISPE-II. Of those, five were almost "textbook" cases for the study of plume washout. Analysis of most samples is nearing completion and it has been determined that the quality of the data is high. Reporting of the results will be done jointly with Battelle PNL and ORNL and conclusions will be placed within the general MAP3S acid rain context.

References

Patrinos, A.A.N. and H.W. Hoffman, 1979: Meteorological effects of thermal energy releases (METER) program annual progress report, October 1977 to September 1978. Oak Ridge National Laboratory Report ORNL/TM-6867.

Patrinos, A.A.N., N.C.J. Chen and R.L. Miller, 1979: Spatial correlations of monthly rainfall: Application in climatology and weather modification experiments. J. Appl. Meteor. 18: 719-732.

Patrinos, A.A.N. and K.O. Bowman, 1980: Weather modification from cooling towers: A test based on the distributional properties of rainfall. J. Appl. Meteor., 19: 290-297.

Patrinos, A.A.N., 1980: Winter study of power plant effects. Oak Ridge National Laboratory Report ORNL/TM-7402.

Patrinos, A.A.N., 1981: Power plant induced rainfall modification: Fact or fiction? The Physics Teacher 19: 173-180.

Title: Technical Assistance for "Radioactive Materials Released from Nuclear Power Plants - 1978, 1979, 1980"

FY 81: $ 40,000

FY 82: $ 50,000

Principal Investigators:
Joyce L. Tichler
Carmen M. Benkovitz
Sponsor: Office of Management and Program Analysis, NRC

The report prepared by BNL for the NRC on "Radioactive Materials Released from Nuclear Power Plants - 1978" was published in March 1981 (Tichler and Benkovitz, 1981). Work was completed at BNL on the "Radioactive Materials Released from Nuclear Power Plants - 1979" report and the report was submitted to the NRC for publication. In July 1981, work was begun at BNL on the 1980 report. For each year, data are taken from reports submitted to the NRC by the nuclear power plants in compliance with NRC Regulatory Guide 1.21. The data are entered into a data base using the SYSTEM 2000 data base management system. Draft copies of the reports are sent to the power plants for approval. Any necessary corrections are made before BNL provides the NRC with printer-ready final reports. BNL also provides the data in computer form to users referred by the NRC.

Reference

Tichler, J. and C. Benkovitz, 1981: Radioactive materials released from nuclear power plants. Annual Report 1978. BNL-NUREG 51192, NUREG-CR-1497.

Title: Probability Modeling of Atmospheric Transport and Diffusion

FY 81: $ 53,000

Principal Investigator:
Paul Michael
Sponsor: Atmospheric Sciences Laboratory, Department of Defense

The program is concerned with developing advanced diffusion and transport models, using probability concepts, applicable to the problem of visibility through smoke screens. This project is developed in three phases. The first phase is the development of an interim model to calculate, in neutral meteorological conditions, the probability of visibility suitable for target detection and weapon use in smoke-screen battlefield conditions. The second phase of the project is the development of a more advanced model applicable to more general meteorological use, and the development of a computer program for the interim model. The scientific approach has been to (1) utilize surface boundary layer meteorological parameterization based on similarity theory together with (2) probability density functions for the concentration of smoke as derived from the conservation of mass equation. A third phase is to use the theory of random processes coupled to micrometeorology in order to establish a theoretical framework for the model development.

With the assistance of a subcontractor, a computer code for the calculation of the probability of visibility through a fluctuating plume has been delivered to the sponsor. Several reports on the application of Markovian processes to meandering plumes have been published (Levin, 1981a, b).

This program has been completed.

References

Levin, A., 1981a: On the description of the turbulent fragmentation of a puff in the turbulent flow with the large Reynold's numbers. BNL 51385.

Levin. A., 1981b: Remarks on the description of the statistical features of the turbulent diffusion of a puff. BNL 51386.

Title: Coastal Meteorological Experiments in the Bay of Bengal During MONEX 79

FY 81: $ 24,000

FY 82: $ 12,000

Principal Investigator: S. SethuRaman

Sponsor: National Science Foundation

The importance of the monsoons as a major energy source for the global circulation of the atmosphere has long been recognized. The seasonally varying circulations associated with the heating and cooling of Asia-Europe-Africa complex is most important, although poorly understood. Monsoon rainfall, which varies in timing and amount from year to year, affects the agriculture and economy of hundreds of millions of people. Prediction of monsoon strengths is virtually impossible without knowledge of the large-scale seasonal monsoon circulations.

In order to understand these processes, a Monsoon Sub-Programme was developed as part of the Global Atmospheric Research Programme (GARP) of the World Meteorological Organization (WMO). It consisted of a coordinated group of observational studies and associated data processing. The central field experiment of the Monsoon Sub-Programme was the Monsoon Experiment (MONEX), which consisted of a group of observational studies during the period of the First GARP Global Experiment (FGGE) over the Arabian Sea, Indian Ocean, Bay of Bengal, and Southeast Asia.

An important synoptic component of the Indian southwest monsoon is the monsoon depressions that form in the Bay of Bengal.

The structure of the depressions has been investigated in the past, but these studies were done after they moved inland where upper air observations were available. One of the main objectives of the summer monsoon experiments (MONEX 79) was to study the monsoon depressions over the Bay of Bengal with instrumented aircraft and ships in addition to ground stations. The marine boundary layer experiment was conducted to supplement aircraft observations and provide information regarding the air-sea interaction processes responsible for cyclogenesis over the Bay of Bengal (SethuRaman et al., 1979).

The experiments were conducted at Digha, West Bengal, India, located at 21°30'N and about 88°E. Atmospheric turbulence, and fluxes of momentum, heat and water vapour were measured from a 10-m-high coastal meteorological tower. Wind speed and direction profiles in the boundary layer were obtained with pilot balloon soundings. Near-surface mean wind speed, direction, air temperature, dew point, temperature, solar radiation and precipitation were measured for 30 days.

Marine boundary layer processes inferred from wind profiles and surface-layer fluxes of momentum and heat indicate a change in the direction of the heat flux (in a vertical plane) depending on the synoptic

conditions. Surface heat flux was upward with small values for those cases with downward heat fluxes in the upper layers (Figure 23). This type of boundary layer process occurred when the monsoon trough was located far northward causing a "break" in the monsoon. When the trough moved to its "normal" position, there was a strong convective boundary layer over the Bay of Bengal (SethuRaman, 1981a, 1981b).

References

SethuRaman, S., P. Michael, W.A. Tuthill and J. McNeil, 1979: An observation system used to study the marine boundary layer over the Bay of Bengal during Summer MONEX 79. Bull. American Meteor. Soc., 61, 1204-1211.

SethuRaman, S., 1981a: Marine boundary layer wind structure over the Bay of Bengal during MONEX 79. WMO GARP Report, 41-47. BNL 29724.

SethuRaman, S., 1981b: Interaction of the atmospheric boundary layer with large scale processes over the Bay of Bengal during MONEX 79. Presented at the International Conference on Scientific Results of the Monsoon Experiment, Denpasar, Bali, Indonesia, 26-30 October 1981.

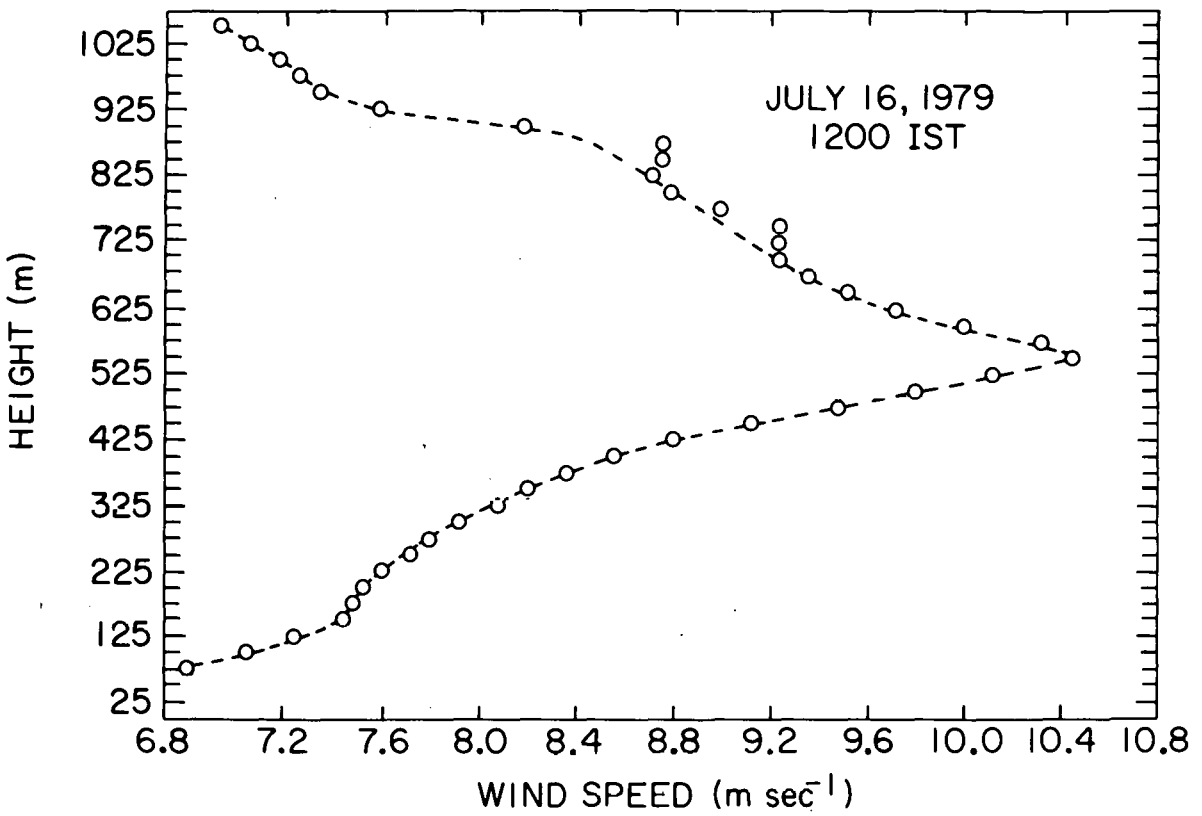

Figure 23. Wind speed variation with height over the Bay of Bengal showing accelerated flow due to a thermal inversion caused by warm air advection from the continent. This type of situation was found to exist during monsoon breaks.

Title: Offshore Coastal Diffusion Studies in the Gulf of Mexico

FY 81: $ 46,000

FY 82: $ 86,000**

Principal Investigators:
Russell N. Dietz*
S. SethuRaman
Sponsor: American Petroleum Institute

Atmospheric turbulence and diffusion over the Gulf of Mexico were studied during the summer of 1981 in cooperation with Stanford Research International, Menlo Park, California. A 10-m micro-meteorological tower was erected at the beach near Cameron, Louisiana. Various meteorological parameters were measured at the beach during onshore flows and were processed on site to obtain statistical parameters for use in conducting the diffusion experiments and for later analysis.

Periodic pilot balloon soundings were made from the beach. During diffusion tests, SF_6 tracer gas and oil-fog smoke were released from an offshore oil-drilling platform. A BNL smoke generator was used for smoke production. Tracer concentrations were measured by SRI personnel who also conducted other aspects of the experiment. Analysis of the meteorological data is continuing. Another experiment during February 1981 is planned.

---

*Environmental Chemistry Division.
**Participation by the Environmental Chemistry Division to the extent of approximately 50% of this budget.

Title: Rainout and Washout of Nitrogen Oxides and Oxyacids

FY 81: $190,000**

FY 82: $ 75,000**

Principal Investigator: Stephen E. Schwartz*

Sponsor: Federal Aviation Administration, Department of Transportation.

A major uncertainty affecting present ability to model the effects of injection of nitrogen oxides in the stratosphere is the net rate of transport of these compounds from the stratosphere to the troposphere. This rate is governed by the rate of removal of nitrogen oxides and oxyacids from the troposphere. This latter process takes place to a large but uncertain extent through interaction with water in clouds and in rain, viz., solution, re-release, and aqueous-phase chemical reaction. The research in this program has been addressing these processes by means of four interrelated areas of investigation: (1) directed review of the literature pertaining to the equilibria and reaction kinetics affecting the solubility of the nitrogen oxides and oxyacids in aqueous solution, (2) modeling the rates of washout and rainout of nitrogen oxides and oxyacids, including chemical reaction, (3) directed fundamental laboratory studies of the solubility equilibria and reaction kinetics important in the aqueous chemistry of nitrogen oxides and oxyacids in the atmosphere, and (4) selected field investigations of rainout and washout of nitrogen oxides and oxyacids in the lower troposphere.

Research in this program commenced in June 1978 and is being brought to completion in FY 1982. Most of the research is conducted by the Environmental Chemistry Division but the Atmospheric Sciences Division cooperates in the field studies.

Directed Review

The first phase of this review (Schwartz and White, 1981a) examined equilibria involving gas- and aqueous-phase NO, NO_2, N_2O_3, N_2O_4, HNO_2, and HNO_3 with emphasis upon dilute aqueous solutions pertinent to the ambient atmosphere, i.e., rain and clouds. Enthalpies and free energies of formation, and gas-, aqueous-, and mixed-phase equilibrium constants were presented in tabular form. Equilibria involving aqueous-phase NO_2, N_2O_3, and N_2O_4 were discussed in detail and recommended values for the Henry's law coefficients were presented.

The second phase of the review (Schwartz and White, 1981b) examined the kinetics of reactive dissolution of the nitrogen oxides into dilute aqueous solution. Kinetic studies reviewed included indirect studies, direct measurements of aqueous-phase reaction rates, and measurements of mixed-phase kinetics. The results of these various studies were compared to obtain recommended values for the pertinent equilibrium and kinetic constants.

---

*Environmental Chemistry Division.

**Participation by the Environmental Chemistry Division to the extent of approximately 85% of this budget.

Other studies pertinent to aqueous-phase reactions of NO_2 and NO with water or aqueous solution were also reviewed.

Modeling

Scavenging coefficients, Λ for the removal of HNO_3 vapor from the atmosphere by both cloud and rain drops were evaluated for assumed models of drop-size distribution (Levine and Schwartz, 1981). For cumulus clouds a value of 0.2 sec^{-1} was estimated. Evaluation of rainfall washout coefficients gave values of Λ ranging from 1.3×10^{-5} to 1.5×10^{-3} sec^{-1}, depending upon the rainfall rate, upon the drop-size distribution function employed, and, strongly upon the lower limit of the raindrop size employed in the calculations. The concentration of soluble gas dissolved within a falling drop per unit fall distance was found to be a function of drop size, with the smaller drops accumulating the greater concentration. The long-term average rate of heterogeneous removal of HNO_3 was estimated in the range $1\text{-}8 \times 10^{-6}$ sec^{-1}, representing comparable contributions from dry deposition and rainfall scavenging.

In a second paper (Lee and Schwartz, 1981a) the rates of aqueous-phase reactions of NO_2 in the ambient atmosphere were evaluated. Reactions

$$(1)\quad 2NO_2(g) + H_2O(\ell) \longrightarrow 2H^+ + NO_3^- + NO_2^- \qquad \text{and}$$

$$(2)\quad NO_2(g) + NO(g) + H_2O\ (\ell) \longrightarrow 2H^+ + 2NO_2^-$$

were found to be quite slow at representative atmospheric partial pressures and cloud liquid water content; the characteristic times range upwards from 10^3 - 10^4 h at 10^{-7} atm, increasing with decreasing partial pressures of the gases. Direct acidification of cloud liquid water by (1) or (2) was also found to be unimportant. Deposition of NO_2 to surface (ocean or lake) water was shown to be controlled by aqueous-phase mass transport and/or reaction and much slower than heretofore assumed.

Laboratory Studies

In the initial review of the equilibrium solubility of the nitrogen oxides (Schwartz and White, 1980) it was shown that at least one of the aqueous-phase equilibrium constants involving these species available in the literature was incorrect. Reexamination (Markovits et al., 1981) of the equilibrium $2\ HNO_2 = N_2O_3 + H_2O(\ell)$ revealed an unexpected dependence of the apparent equilibrium constant upon acidity at high acid concentrations where previous studies had been conducted. The value of the equilibrium constant obtained at low acidities is consistent with values estimated thermochemically.

The reaction $2NO_2(g) + H_2O(\ell) \longrightarrow 2H^+ + NO_2^- + NO_3^-$ was studied by contacting dilute NO_2 in N_2 with liquid water in a reactor of known and variable mass transfer characteristics (Lee and Schwartz, 1981b). The rate of reaction was consistent with second-order kinetics, and the values of the Henry's law coefficient of NO_2 and of the aqueous-phase rate constant were

determined. Subsequently (Lee and Schwartz, 1981a) it was shown that the presence of O_2 (0.2 atm) exerted no influence upon this reaction.

Field Studies

Under the assumption of chemical equilibria it may be established that in the presence of clouds or fogs of typical liquid water content ($\gtrsim$ 0.1 g/m^3) NO_2 should react essentially completely to give nitric and/or nitrous acids. To examine this it was intended to measure NO_2 gaseous concentration and concentrations of dissolved nitrogen oxyacids in fog liquid water. To this end a fog water collector was constructed, based upon an impactor principle. Limited testing of this device indicated inadequate sample collection rate for fogs typically encountered at this location. In view of the rarity of suitable fog events these studies have been discontinued.

References

Lee, Y.-N. and S.E. Schwartz, 1981a: Evaluation of the rate of uptake of nitrogen dioxide by atmospheric and surface liquid water. J. Geophys. Res., in press.

Lee, Y.-N. and S.E. Schwartz, 1981b: Reaction kinetics of nitrogen dioxide with liquid water at low partial pressure. J. Phys. Chem. 85: 840-848.

Levine, S.Z. and S.E. Schwartz, 1981: In-cloud and below-cloud scavenging of nitric acid vapor. Atmos. Environ., in press.

Markovits, G.Y. , S.E. Schwartz, and L. Newman, 1981: Hydrolysis equilibrium of dinitrogen trioxide in dilute acid solution. Inorganic Chemistry 20: 445-450.

Schwartz, S.E. and W.H. White, 1980: Equilibrium solubility of the nitrogen oxides and oxyacids in aqueous solution. Report BNL 27102.

Schwartz, S.E. and W.H. White, 1981a: Solubility equilibria of the nitrogen oxides and oxyacids in dilute aqueous solution, in Advan. Environ. Sci. Eng. 4, J.R. Pfafflin and E.N. Ziegler (Eds.), Gordon and Breach, New York. pp. 1-45.

Schwartz, S.E. and W.H. White, 1981b: Kinetics of the reactive dissolution of the nitrogen oxides and oxyacids in aqueous solution. Report BNL 30178.

Title: Cloud Water Acidity Measurements and Formation Mechanisms

FY 81: $131,000**

FY 82: $645,000**

Principal Investigator: Stephen E. Schwartz*

Sponsor: Electric Power Research Institute

A major uncertainty restricting the present ability to describe atmospheric transformations leading to acid rain formation is that of describing incorporation of acidic materials into condensed phase water in clouds. Such incorporation may take place by one or both of two routes: (1) extra-cloud oxidation of sulfur and nitrogen oxides to the corresponding acids followed by incorporation of these acids by cloud liquid water, and/or (2) uptake of the gaseous oxides by cloud liquid water, followed by aqueous-phase reaction to form the acids. This program represents a concerted effort to elucidate these processes, consisting of field measurements, instrument development in support of these field measurements, laboratory studies of kinetics of gas-aqueous reactions, and analysis and interpretation.

The objectives of this program are as follows:

1. Measure concentration fields of relevant species (including horizontal and vertical variability) within clouds and in the in-flow clear air regions. These species include gases SO_2, NO, NO_2, HNO_3, O_3, H_2O_2, NH_3; aerosol H^+, $SO_4^=$, NH_4^+, NO_3^-; and cloud water constituents H^+, NH_4^+, $SO_4^=$, NO_3^-, and H_2O_2.

2. Examine equilibria, by evaluation of Q/K, where Q is the stoichiometric quotient,

$$Q = {}_i\pi C_i / \pi_j C_j$$

and K is the corresponding equilibrium constant. To carry out this it is necessary to estimate the noise in each of the C_i, as determined from concentration fluctuations either measured directly (i.e., real time instrumentation) or, in the absence of real time measurements, inferred from fluctuations in the concentrations of species actually measured.

3. Evaluate rates of aqueous-phase chemical reactions occurring in cloud liquid water, from measured reagent concentrations making use of reaction mechanisms and rate constants as determined from laboratory measurements.

4. Evaluate rates of physical incorporation of acidic material into clouds, making use of known concentrations and measured flow fields.

---

*Environmental Chemistry Division.

**Participation by the Environmental Chemistry Division to the extent of approximately 75% of this budget.

This program commenced on July 1, 1981 and is a cooperative effort between the Environmental Chemistry Division and the Atmospheric Sciences Division with the former having the leading role. Highlights of accomplishments in the period July 1 to October 31 are as follows.

Instrumentation

An axial-flow cyclone cloud water collector and gas separator was constructed. Initial testing indicated that the cyclone operates effectively but that there appears to be inefficient extraction of centrifuged cloud water by the collection ring. Modification of the collection ring resulted in improved extraction, but further modification appears indicated. Hardware was designed and constructed to adapt the outflow of the CWC/GS to Hi-Vol filter sampling.

The Abbas-Tanner continuous NH_3 analyzer (fluorescence derivatization principle) was adapted for aircraft use. Limited testing indicated limit-of-detection ca. 0.25 ppb, noise ca. 0.1 ppb, and time-response ca. 2 min. NH_3 concentrations of 0.25 to 1.5 ppb were measured at altitudes 500 to 2,500 ft.

A high-sensitivity, dual-channel NO_x analyzer ($NO-O_3$ chemiluminescence) was designed (modification of commercial instrument), and construction was initiated. The modified instrument will be operable in simultaneous NO_x, NO_x-HNO_3 or NO_x, NO modes. A limit-of-detection of 0.1 ppb in each channel is expected, based on experience with a similarly modified single channel analyzer.

Field Measurements

A set of scoping measurements was undertaken to test measurement capabilities and to examine feasibility of the intended sampling flights. In-cloud sampling under FAA air traffic control was shown to be entirely suitable to the needs of this program. Cloud liquid water samples were obtained on five missions. Liquid-water sample collection rates were variable, depending on liquid water content.

Laboratory Studies

An experiment was designed to measure the rate of aqueous-phase reaction of NO_2 + S(IV) at constant pH. As shown previously, the oxidation of HSO_3^- by NO_2 produces one H^+ ion per HSO_3^- oxidized. The pH will be sensed and base added by a servo device at a rate necessary to maintain constant pH. The reaction rate will be determined from the required rate of base addition. The necessary equipment was acquired and set up, and feasibility of the technique was demonstrated.

Analysis and Interpretation

A schedule was prepared detailing the components of a mission, including computer processing of aircraft data and compilation of supporting meteorological documentation. Mission documentation files were prepared for the five scoping missions that were conducted.

Title: Aircraft Operations

FY 81: $209,000**

FY 82: $188,000**

Principal Investigators:
Peter H. Daum*
Robert M. Brown
Sponsor: Office of Research and Development, EPA

The Britten Norman "Islander" research aircraft (Leahy, 1981) is used in support of several research programs. Considerable development and modification of aircraft instrumentation has occurred in the last year to enhance our ability to measure trace concentrations of gases and particles in the atmosphere, and to provide new capabilities so that questions relating to the formation and deposition of acid precipitation can be addressed. The details of these developments are discussed below.

Cloud Water Collectors

Both ASRC (Atmospheric Sciences Research Center) and CERL (Central Electric Research Laboratories) designed cloudwater collectors have been installed on the BNL aircraft. The ASRC unit consists of an array of slotted Teflon rods connected to a vacuum source. Cloud water droplets impact the rods, drain down the slots in the tubes, and are collected in a jar. The device is exposed to the slipstream by insertion through a port in the aircraft roof that was fabricated for this purpose. The CERL device consists of a static angled vane system contained within a 46 mm ID tube through which the cloud sample flows. Cloud droplets are thrown to the side of the collector downstream of the vane system and are collected by means of a collection ring. Droplet free air exiting the collector can be directed to the BNL filter pack sampling system so that gases and particles in the interstitial cloud air can be sampled.

Scoping missions indicate that both devices collect cloudwater samples with useful efficiency. Chemical analysis of the samples indicates that the chemical composition varies widely depending on altitude and airmass source.

Chemical Instrumentation

Developments in chemical instrumentation include devices for measurement of gaseous ammonia, NO_x and nitric acid and sulfur dioxide and aerosol sulfur. The ammonia instrument operates by scrubbing the incoming air sample with a dilute solution of sulfuric acid in a simplified venture scrubber. The scrubbed stream is passed through a gas/liquid separator and the liquid portion analyzed using a fluorescent derivatization technique. The detection limit of the method is ca. 0.25 ppb of ammonia in air, and the response time is on the order of 2 minutes. Results of preliminary airborne

*Environmental Chemistry Division.
**Participation by the Environmental Chemistry Division to the extent of approximately 50% of this budget.

testing indicate that the device will be useful for determining the spatial variation of ambient ammonia concentrations.

A Meloy 285 sulfur analyzer has been modified to reduce response variations caused by altitude changes and to simultaneously measure both SO_2 and aerosol sulfur. Sample air for the instrument is divided, one portion passed through a lead oxide-glycerine denuder tube to remove gaseous sulfur and the second passed through a quartz filter to remove particulate sulfur. Each stream is then routed to a separate flame photometric detector. Signal from the first detector is due solely to aerosol sulfur while that of the second is due only to gaseous sulfur compounds. Electronic mass flow controllers connected to the hydrogen supply and to the exhaust gas stream effectively control the sample flow rate and flame characteristics. This automatically compensates for sample flow variations caused by altitude (inlet pressure) changes.

A TECO, model 14B chemiluminescent based NO_x analyzer has been modified to improve sensitivity and to measure nitric acid. Alterations include the installation of a larger reaction chamber with an internal reflective surface and the use of a high capacity rotary pump which allows the chemiluminescent reaction to occur at lower pressure, thereby reducing quenching of the emitting species. These modifications enhance the detection of chemiluminescence from the reaction of NO with internally generated ozone thereby increasing sensitivity. A front panel actuated solenoid that diverts the sample air stream through a pre-reactor allows precise measurement of instrument zero. Three parameters are measured by the instrument, NO, NO_x and $NO_x + HNO_3$.

Reference

Leahy, D., 1981: The Brookhaven National Laboratory Atmospheric Sciences Aircraft, BNL-28102R.

Title: Meteorology Service

FY 81: $ 78,000

FY 82: $ 69,000

Principal Investigator:
Robert M. Brown
Sponsor: Distributed services

Since its formation as the Meteorology Group, the Atmospheric Sciences Division has had a strong service function in addition to its research programs. Numerous services are continually being supplied to other Laboratory departments. Some of these are made possible by facilities originally acquired primarily for research purposes but used jointly and all are made possible by the training and experience of the staff. These services involve technicians, programmers and computer aides as well as professional staff. They require the maintenace of meteorological facilities and instruments plus teletype and facsimile machines.

The weather and climate at BNL differ significantly from those in New York City and even those near the shorelines of Long Island. Therefore, data from other weather stations and forecasts prepared by the National Weather Service or private firms not familiar with local conditions are not always applicable to the site. Thus, the meteorological data accumulated here over a thirty-year period is a unique and valuable resource for which additional uses are constantly being found and the local experience of the staff is indispensable in providing guidance for weather related problems.

The Department of Energy has recently mandated that the operation of the High Flux Beam Reactor (HFBR) at BNL meet the requirements established by the Nuclear Regulatory Commission (NRC) for the safe operation of a commercial nuclear power plant. The meteoroloigcal requirements which pertain to the mandate are given in Appendix 2 of NRC NUREG 0654. The Atmospheric Sciences Division is cooperating with Safety and Environmental Protection Division personnel in establishing an emergency system for coping with the rules and regulations given in Appendix 2.

Service functions of the Division can be grouped into the following categories.

1. Installation, calibration, maintenance and operation of meteorological facilities and instruments.

2. Data reduction including chart reading and processing of magnetic tapes.

3. Conversion of data into usable forms including hourly, daily, monthly and annual means.

4. Establishing and updating meteorological and climatological data bases.

5. Maintenance of weather information facilities, teletype and facsimile.

6. Analysis of weather data and preparation of daily forecasts.

7. Preparation and dissemination to other departments of warnings of hurricanes, high winds, thunderstorms and snow storms.

8. Performing diffusion calculations for Reactor Division and S and EP Division.

9. Providing data for scientific programs in other BNL departments.

10. Providing data for BNL planning purposes including energy conservation programs.

11. Providing data and forecasts for BNL weather-sensitive operations.

12. Providing similar information to BNL contractors and consultants.

13. Providing data for dissemination by Public Relations.

14. Loan of instruments to and calibration of instruments for other departments.

BNL's climatology record (Nagle, 1975, 1978), existing on tape for 1960 to the present, will prove of even greater value in view of increased interest in alternate forms of energy production such as solar and wind power. Brookhaven's climatology record includes winds measured hourly at more than one altitude for the entire data period. Most climatology stations have wind measured only at one height.

In June 1977 a pyrheliometer was installed at our site. Pyranometer data have been part of our climatology records since April 1967. Brookhaven is one of the few stations that has an hourly record of both total and direct solar radiation. The solar data are requested by numerous users and will become more and more valuable as the length of the record increases.

Examples of services provided recently include:

1. Diffusion calculations for HFBR at 60 mw.

2. Information and calculations for the solar energy programs including the heliostat.

3. Operational forecasts for oceanography activities.

4. Diffusion calculations for particulate emissions from combustor at Building 835.

5. Data and calculations for energy conservation program.

In addition to services within BNL, the Division responds to many requests for information from other organizations as part of the information dissemination responsibility of the Laboratory.

References

Nagle, C.M., 1975: Climatology of Brookhaven National Laboratory 1949 through 1973. BNL 504661.

Nagle, C.M., 1978: Climatology of Brookhaven National Laboratory 1974 through 1977. BNL 50857.

FUTURE PLANS

MAP3S/RAINE Program Direction

In FY 1982 the MAP3S/RAINE project directorship will be held by Paul Michael of BNL. MAP3S/RAINE is an interlaboratory effort aimed at gaining a physical understanding of the processes that deliver atmospheric pollutants to the surface so that a mathematical description can be constructed. The nature of this program requires a multidisciplinary effort and a high degree of coordination. The Program Director works in conjunction with a Steering Group, which is staffed by representatives of the principal participating laboratories.

The broad objective of the MAP3S/RAINE Program Direction task is to provide leadership and coordination for the prosecution of the scientific program directed at obtaining the knowledge needed to assess the impact of pollutants deposited to the surface. The details of the program plan are contained in the MAP3S/RAINE Program Design-Basis Document (PNL-3424 UC-11) which is prepared by the participants and subject to review prior to implementation.

Specific sub-objectives of the MAP3S/RAINE Program Direction task are:

1. To insure that the research program is conducted in such a manner as to optimize research productivity.

2. To coordinate the MAP3S/RAINE research program with other related programs.

3. To insure the dissemination of MAP3S/RAINE activities and results to the general scientific community and to relevant user groups within EPA.

4. To coordinate the use of MAP3S/RAINE results and resources on current national and EPA problems.

5. To serve as a point of contact between the EPA staff and the MAP3S/RAINE researchers.

The key aspect in achieving the above-stated objectives is the organizational structure of MAP3S/RAINE. This organizational structure is defined in the program Design Basis Document. Central control of the program is exercised by the MAP3S/RAINE Program Director, who answers directly to the EPA Project Officer.

Conduct of the scientific research programs within MAP3S/RAINE is directed and monitored by the Program Director and the MAP3S/RAINE Steering Group. The Steering Group is staffed by representatives of the three principal MAP3S/RAINE National Laboratories. Recommendations with regard to funding, research emphasis, experiment design, resource allocation, and policy are formulated by the Steering Group and are submitted to the EPA Project Officer via the Program Director.

Coordination of the external atmospheric research activities is conducted via the MAP3S/RAINE Coordination and Review Group. Members of this group are selected to provide a diverse representation of ongoing research programs and institutions related to the MAP3S/RAINE effort. Membership of the Coordination and Review Group will be periodically reviewed to insure adequate representation from groups doing relevant research.

Primary functions of the Coordination and Review Group are:

1. Liaison and coordination between MAP3S/RAINE and peripheral research activities; and

2. Review of MAP3S/RAINE operations.

Coordination and Review Group members receive and are invited to comment on all MAP3S/RAINE output prior to publication. They are also encouraged to review program and experiment plans, and to participate jointly in cooperative field efforts as the opportunities arise.

1. The optimization of the research effort is carried out with the aid of the Steering Group; frequent discussions will be held on the scientific content of ongoing activities in order to insure their relevance to the program, to minimize duplication and to insure that all important aspects of the program are being adequately covered.

Peer review of the program will be provided for by continual communication with the Coordination and Review Group and the convening of biennial formal review meetings. The formal review meetings will form the basis for revising the Design Basis Document.

2. Coordination with external research groups will be carried out by frequent communication with the Coordinating and Review Group; all MAP3S/RAINE publications will be sent to them routinely. In addition they will receive prompt notification of MAP3S/RAINE plans as they are developed. The members of the Coordination and Review Group will be encouraged to communicate news of their related research to the MAP3S/RAINE researchers both directly and via the Program Director. As the need for wider dissemination of MAP3S/RAINE news is indicated a "MAP3S/RAINE Director's Letter" will be mailed to a broad distribution list.

3. The primary avenue for the dissemination of results from the MAP3S/RAINE program will be open literature publications. This will be augmented by topical reports on specific developments. The prime role of the MAP3S/RAINE Director will be to encourage the participants to publish promptly and to aid in dissemination to potential user groups such as OAQPS, EPA Regions, and the US/Canadian Transboundary Air Pollution negotiating team.

4. As needs for the use of MAP3S/RAINE resources (e.g., model calculations, scientific analysis, use of equipment, etc.) develop within EPA, or perhaps elsewhere in the Government, the MAP3S/RAINE Director will consult with the persons requesting the assistance, comment upon the appropriateness of diversion from the research tasks, help to evaluate the impact upon the

program, recommend which resources can most effectively be used, and assist in the revision of the program plan to account for such activities.

5. Coordination between the EPA Project staff and the MAP3S/RAINE researchers will occur by means of frequent contacts with the EPA staff. As specific issues or questions arise the Program Director will either handle them directly or, if more efficient, refer the EPA staff member to the appropriate researcher. From time to time, summaries of the bimonthly letter reports will be prepared and disseminated.

A review of the MAP3S/RAINE program was held by the Coordination and Review Group in November 1981. The recommendations of this group will be used to evaluate progress made to date and the program plan. A revised program plan will be developed and issued in June of 1982.

Expected publications in FY-82 will include a MAP3S/RAINE biannual progress report, a revised Program Design Basis Document, a summary report on the OSCAR experiment and several issues of the MAP3S/RAINE "Director's Letter" giving general information on the MAP3S/RAINE status and progress.

At the end of FY 83 a biannual Progress Report covering the activities of 1982 and 1983 will be published.

A program review will be held in the fall of 1983; at that time the program status will be evaluated and a determination of new directions made.

There will be increased emphasis upon the transfer of results and methodologies to user groups.

MAP3S/RAINE Modeling Program

Items that are expected to be emphasized in the modeling effort during FY 1982 are:

1. Development of the 2-D pseudospectral model with appropriate routines for filtering and conservation. Application to the $SO_2/SO_4^=$ problem with realistic emissions, simple winds, and linear chemistry.

2. Incorporation of the computational modules of the model into the Framework program.

3. Formulation of the objective analysis of winds for the expanding grid. Testing of item 1 with realistic winds.

4. Development of the nonlinear chemical reaction software package. Testing with select species and incorporation into Framework program.

5. Application of the chemical reaction software package to all important chemical species.

The general program directions beyond FY 1982 are expected to include the following:

1. Extension of model to 3-D with a "layer" approach.

2. Development of advanced routines for the incorporation of wet deposition.

3. Comparison of model results with data, modifications, and final verification.

4. Release of a user-oriented version of the model.

Interregional Air Quality

A continuing concern will be the effect of stack height upon SO_2 and SO_4 impacts.

Long range transport modeling efforts will begin to shift from sulfur chemistry to the photochemical oxidants. Our overall concern is in determining, on a regional scale, the rate of formation of acidic sulfate and nitrate as a function of precursor emissions. Transport considerations in the first calculations will be simplified to single representative trajectories traversing "interesting" source and receptor areas. A trajectory will define the motion of a parcel of air, in which we model the time evolution of smog-type pollutants. A realistic emission inventory for sulfur oxides, nitrogen oxides, and hydrocarbons will be used to provide pollutant input to the traveling air parcel.

FIELD AND LABORATORY STUDIES

Precipitation Chemistry Studies

Four programs involve precipitation chemistry and related subjects.

A. Plans for the four studies conducted under the MAP3S/RAINE are described separately.

1. In the study of relationship of within-event precipitation composition changes to meteorology, trajectory and concurrent air pollution concentrations sequential sampling of all precipitation events will be continued in FY 82. Additional measurements of atmospheric chemistry before, during and after events will be obtained. Precipitation chemistry at ground level will be compared to cloud water and rain chemistry aloft and related to low-level and aircraft measurements of air pollutants. Additional trajectory studies will be made to determine source regions of pollutants. If funds permit, a second sequential sampler will be constructed and operated at an inland location. Otherwise, sequential samples will be obtained manually for limited time periods. Expected publications include a statistical report on precipitation chemistry--meteorology relationships based on five years of data, a study of changes within events as related to meteorological factors, a study of the relationships between cloud water and air chemistry aloft and rainwater chemistry at the ground and a study of pollutant source regions as determined by trajectory analyses. In later years, sequential sampling at BNL and at an inland location will be continued if

required to obtain adequate data. Analyses will be performed to determine how the effects of meteorological conditions differ at inland and coastal locations. Findings of the study will be applied to models of pollutant transport and wet removal.

2. In the study of effects of urban sources on regional precipitation chemistry, a small network of event-type and manually operated sequential samplers will be operated at selected locations around the New York City area during related precipitation events. Synoptic and meteorological analyses will be made of each event. Where practical, ambient measurements of air and cloud water chemistry will be made upwind and downwind of the urban source. Ground-level air chemistry will be measured at selected locations. Pollutant emissions will be estimated from available inventories. Results will be analyzed to determine the effects of the urban source on downwind precipitation chemistry. Expected publications include a paper on the distance downwind to which a city influences precipitation chemistry, and a paper on the effectiveness of urban plume washout. Finally, experimental data will be analyzed in terms of urban contributions to precipitation composition and washout efficiency and results applied to diffusion and deposition models.

3. The equilibrium effects on precipitation scavenging of aerosols and gases study will concentrate on making measurements from the BNL instrumented aircraft which will provide vertical profiles of key species in non-precipitating atmospheres and allow tests of adherence phase equilibria as a function of vertical distance (Z) from the surface in at least two seasons. An additional ground-level phase equilibrium experiment at BNL during a precipitation event (preferably snow) may also be conducted. Considerable effort will be expended in evaluation of data collected during OSCAR, especially comparing $[NH_3]$, $[HNO_3]$ and their product with calculated values.

Major effort in future years will be in conducting phase equilibrium experiments, measuring species important to ionic composition in hydrometeors from an aircraft platform as a function of height during precipitation events. Simultaneous ground-level experiments during some of the Long Island area flights will also be attempted. Detailed comparison of calculated and observed values of species involved in dynamically changing equilibria during scavenging processes as well as clear air transport should provide the basis for simplified modeling of ionic incorporation phenomena.

4. Further development of instrumentation for conduct of the proposed experiments in the cloud processing studies will occur in FY 1982. A system for supplying droplet-free air for the aircraft filter pack sampling system will be developed, testing of the new real time instrument for NO_x and HNO_3 will occur, and acquisition and/or development of devices to determine cloud droplet size distribution and vertical wind velocities will be initiated. Flights with currently available instrumentation will be made to provide preliminary data so that a full scale field program can be planned for FY 1983. In future years, more complete measurements of air chemistry and cloud characteristics will be made in full scale field operations using new and improved instrumentation. Both stratiform and convective clouds will be studied in precipitating and non-precipitating states. Vertical velocities

into clouds will be measured. Rates and mechanisms will be related to cloud type and characteristics, types and concentrations of air pollutants and meteorological conditions. Findings will be applied in modeling programs.

B. The METER Program will be completed in FY 1982. For the precipitation modification study, the entire three-year data set will be subjected to the rigorous statistical treatment which is in the final stages of development. The data base of approximately 500 storms is expected to provide qualitative and quantitative indications of the power plant's potential effect on rainfall. The results will appear in the final METER report to be published by ORNL.

As mentioned earlier, the results of WISPE II will be reported jointly with PNL. Most chemical analyses of the precipitation samples have been completed and analysis of select air filter samples is planned for the first part of FY 82. The main activities will concentrate on the critical evaluation of all available data and the integration of the meteorological, air chemistry, and rainfall chemistry data into comprehensive model frameworks of pollutant scavenging and deposition.

C. As noted above the rainout and washout of nitrogen oxides and oxyacids program will be concluded in FY 1982. Plans for this year include preparation of a journal article detailing the laboratory investigation of the reaction $NO_{(g)} + NO_{2(g)} + H_2O_{(\ell)} \rightarrow 2H^+ + 2NO_2^-$, and completion of the review examining the uptake of atmospheric nitrogen oxides by aqueous-phase reactions.

D. Activities to be undertaken in the cloud water acidity measurements and formation mechanism program in FY 1982 are as follows:

1. Continued development and testing of instrumentation to de deployed, including NH_3 measurement, high sensitivity NO_x mesurement, cloud water collection and separation, real time measurement of conductivity of liquid-water samples.

2. Development of a detailed experimental plan describing aircraft measurements and analysis and interpretation of results.

3. Development of overall program quality assurance plan.

4. Systematic examination of concentration fields and flows governing incorporation of acidic materials into non-precipitating stratiform clouds.

5. Examination for chemical equilibria based upon measured concentrations, and evaluation of chemical kinetic rates.

6. Systematic examination of the mechanism and rate of aqueous-phase reaction of NO_2 with dissolved S(IV) including pH dependence.

Boundary Layer Studies

Three programs involve boundary layer studies.

A. Under the planetary boundary layer studies at land-sea interfaces program, a variety of future activities is planned. At the present experimental site, additional SF_6 and smoke diffusion experiments will be conducted under conditions not yet documented to determine diffusion conditions under a full range of meteorological conditions, time of day and season. Measurements are needed of the coastal internal boundary layer at other coastal locations to determine the generality of the relationships found on Long Island and to verify the mathematical prediction formulation developed by us and others.

Completion of the current program, however, is not enough for adequate evaluation of the effects of energy-related facilities and activities on the environment and the effects of the environment on such facilities and activities in the coastal zones of the U.S. Situations with more complex geography, terrain and meteorology remain to be studied. The additive and possibly synergistic effects of a variety of emissions from numerous sources in a restricted area have not been investigated. We believe that Long Island Sound, which is ringed by many fossil-fuel and nuclear power plants, is representative of other industrialized estuarine areas such as Delaware and Chesapeake Bay and is an ideal laboratory for future studies.

Our plans have been to shift our research activities to Long Island Sound as research on the south shore of Long Island is completed. We anticipate cooperation from LILCO and other utilities in the use of existing towers and facilities. The focus of our program would be the effects of complex geography and meteorology and emissions from multiple energy-related sources on the air quality of the region. We would build on our south shore experience and on our Northport plume studies. We would seek to understand and to model the complex meteorological processes such as opposing sea breezes, multiple internal boundary layers, diverging and converging winds and large seasonal changes in surface and synoptic conditions. We would study their effects on diffusion as a means of evaluating the relationships of an array of energy-related pollutant sources to the environmental quality of the region.

Continued research over the ocean is also necessary to fulfill various needs relating to energy production and transportation. The coastal and marine meteorological studies conducted thus far have indicated that the meteorology over the ocean is quite different from that over land. A knowledge of the time scales of atmospheric turbulence and the generation of waves and currents due to wind forcing is very important for the engineering design of energy-related off-shore structures. At present these are designed with insufficient knowledge of the marine meteorological processes leading to either unnecessarily high costs in construction or to failure due to severe stresses in certain components. Data being obtained are also directly applicable to the potential problem of LNG spills.

B. The coastal meteorological experiments in the Bay of Bengal during MONEX 79 program is nearing completion. Analysis of data collected under the MONEX program will be continued and results prepared for publication.

C. Further activities are planned under the offshore coastal diffusion studies in the Gulf of Mexico program. A second series of field experiments will be conducted in February 1982 at Cameron, Louisiana. ASD personnel will again conduct micro-meteorological measurements and make pilot balloon soundings from the beach. Diffusion tests from an offshore oil drilling platform will also be conducted using SF_6 gas and oil-fog smoke. Following the field experiments, data collected will be analyzed.

Aircraft Operations

Future plans involve further development of aircraft instrumentation and its use in various experiments designed to address questions relating to the formation and deposition of acid precipitation. One set of experiments will attempt to establish the role of clouds in the transformation and relocation of acid precipitation precursors. These experiments will involve measurement of concentrations of important ionic and gaseous species above, below and within clouds. Cloud water will be collected for subsequent chemical analysis. From these measurements identification of those species for which cloud processing is important will be attempted.

Other experiments will attempt to assess the relative importance of the processes of rainout and washout to precipitation chemistry. In these experiments, cloud water and precipitation samples will be collected at ground level and at various altitudes and their concentrations will be related to the vertical concentration profiles of selected chemical species. Finally, experiments will be done to gather information on all pertinent components in the aerosol sulfur, nitrate-gaseous ammonia, nitric acid system to ascertain whether phase equilibria between these species exists.

DATA MANAGEMENT AND ANALYSIS

MAP3S/RAINE Central Data Coordination

Tasks for the Central Data Coordination function are driven by the programatic needs of the MAP3S/RAINE program and, as such, are subject to redefinition during each fiscal year. The following tasks are currently anticipated for FY 82:

1. Maintenance and upgrade of the source emissions inventory. Continued development of gridding techniques.

2. Combined precipitation chemistry data base will be implemented and used.

3. Computational technique to grid precipitation data will be generalized to allow user defined grids.

4. Maintenance and upgrade of meteorological data base for HITTM.

5. Integration and dissemination of OSCAR-generated and auxiliary data will continue.

Anticipated technical publications include reports on the status of the MAP3S data bank, the status of the source emissions inventory; report(s) on the development, implementation and results of the OSCAR data coordination function.

NEROS

In fiscal year 1982, BNL will establish and evaluate a complete Baltimore-Washington data base including meteorological and chemical measurements obtained from a number of platforms, covering the 19 flight days of the NEROS 1980 urban plume study. The quality of the various chemical data bases will be assessed. Each experimental day will be characterized in terms of pertinent parameters. For some subset of the days, the data will be reviewed to determine the geographical boundaries of the Baltimore and/or Washington urban plume.

NRC Effluent Project

BNL will complete the report on Radioactive Materials Released from Operating Nuclear Power Plants - 1980 in FY 82 and should begin work on loading the data for 1981 releases into the data base.

Workshop on Atmospheric Dispersion Models for Emergency Planning

Brookhaven National Laboratory will organize, conduct, and summarize a workshop to solicit and synthesize the inputs and comments of users of the U.S. Nuclear Regulatory Commission's regulations for atmospheric dispersion modeling in support of radiological emergency response plans for nuclear power plants. The proposed workshop will be conducted with the assistance of SRI International during December 1981. A set of proceedings and a workshop summary will be prepared to allow consideration of the outputs by NRC in developing additional emergency planning guidance and to enable the information to be used by operators and applicants in preparing their emergency response plans.

The Workshop on Atmospheric Dispersion Modeling for Emergency Planning will address two basis objectives: (1) provide technical guidance to operators of nuclear power plants and applicants for licensing to enable them to develop emergency response plans, and (2) provide a forum that will enable operators and applicants to give feedback and recommend changes to the guidance and criteria already developed by NRC.

ABSTRACTS OF PUBLICATIONS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

JOURNAL ARTICLES

Benkovitz, C.M., 1981: Compilation of an inventory of anthropogenic emissions in the United States and Canada. Atmos. Environ. (in press). BNL 29008R.

ABSTRACT

The quantification of anthropogenic emissions of pollutants is a key task of the Multistate Atmospheric Power Production Pollution Study (MAP3S). The emissions inventory project has been based on obtaining pertinent data gathered by other agencies. This article describes the data obtained and the methodologies developed to organize, merge, and manipulate these data so as to provide input and answers to researchers participating in MAP3S. Summaries derived from the data currently available are included to present an overview of the current status of anthropogenic emissions in the United States and Canada.

Brown, R.M. and S. SethuRaman, 1981: Temporal variation of particle scattering coefficients at Brookhaven National Laboratory, New York. Atmos. Environ. 15, No. 9, 1733-1737. BNL 27000R.

ABSTRACT

Real-time measurements of scattering coefficients of particles in the atmospheric boundary layer were continuously measured during 1975 and 1976 at a height of 106 m at Brookhaven National Laboratory, Long Island, New York to study their variations with meteorological parameters and in relation to upwind source regions. Short and long time scales of fluctuations, frequency distributions, stagnation periods, and effects on incoming solar radiation were investigated. Results indicate seasonal dependence and variations due to the upwind location of sources.

Lee, H. N., 1981: A multi-step multi-grid numerical model of chemical transport and diffusion in the atmosphere. J. Appl. Meteorol. (in press). BNL 27799.

ABSTRACT

An efficient and accurate multi-step multi-grid model is developed to study chemical transport and diffusion in the atmosphere. The multi-step multi-grid numerical method is the kind of new technique which in time direction uses the variable order of polynomial and the variable size of time step and in space domain uses a set of different grid sizes to approximate the computational domain for the solution process. In this preliminary study, the multi-step multi-grid numerical results agree well with the analytical solutions and with the numerical solutions calculated from EPISODE computer package.

Lobecher, R.N., S. SethuRaman, and G. Field, 1980: SATDAS - for air-sea interaction data acquisition using satellite telemetry. Bull. Am. Meteor. Soc. 61, 1212-1222.

ABSTRACT

SATDAS (Satellite Data Acquisition System) is a data acquisition system utilizing a satellite telemetry link that has been developed for Brookhaven National Laboratory, Upton, N.Y. It is to be used for air-sea interaction and oceanographic experiments. It is microprocessor-based with all functions under software control. These include data interrogation and acquisition, timing control, tape storage, and data telemetry. Data processing programs are included to calculate averages, variances, and covariances. Diagnostic routines are included for system self-test. The use of the microprocessor has resulted in a very simple configuration with an accordingly high level of reliability. Telemetry to shore is via the GOES (Geostationary Operational Environmental Satellite). SATDAS provides a unique combination of in situ processing, system self-check, on-board recording, and satellite telemetry.

Meyers, R.E. and E.E. O'Brien, 1981: The joint pdf of a scalar and its gradient at a point in a turbulent fluid. Combustion Science and Technology 26, Nos. 3 and 4: 123-134. BNL 28287.

ABSTRACT

A closed model equation is derived which describes the evolution of the single-point, joint probability density function of a reacting scalar and its gradient in a turbulent advection field. To obtain a closed form a relaxation model is assumed for molecular diffusion and a white noise Kubo approximation for the advection. With this model, the roles of mean velocity, molecular mixing, chemistry and turbulent advection are examined for their effects on the statistics of a transported scalar and its gradient. It is shown that their joint statistical dependence becomes less significant as the Reynolds number increases. An analogy between transport in composition space due to chemical reaction and mass conservation in compressible gas dynamics leads to a methodology for determining the statistical dependence induced by chemical reaction.

An application of the model to the turbulent advection of an isotropic scalar gradient field shows that it yields a transition probability for the logarithm of the magnitude of the gradient which is a simple random walk with outward drift; that is, with increasing magnitude of the gradient. The time scale of both the drift velocity and the variance is determined.

Michael, P., M. Hoffert, M. Tobias, and J. Tichler, 1981: Transient climate response to changing carbon dioxide concentration. Climatic Change 3, No. 2: 137-153. BNL 27837R.

ABSTRACT

The time-dependent response of climate changes to changing atmospheric concentration of carbon dioxide is modeled using an energy balance atmospheric model coupled to a one-dimensional upwelling diffusion model of the deep ocean. Such a model introduces time delays so that the calculated globally-averaged temperature lags that which would be predicted by assuming radiative equilibrium. The climate model is coupled to a simple carbon cycle model and a 'social' model that simulates decreasing emission in response to increasing global temperatures. The thermal inertia of the system is such that temperatures continue to increase after carbon dioxide concentrations are decreasing.

Raynor, G.S. and J.V. Hayes, 1981: Acidity and conductivity of precipitation on central Long Island, New York, in relation to meteorological variables. Water, Air, and Soil Pollution 15: 229-245. BNL 27529.

ABSTRACT

Three years of hourly sequential precipitation samples from central Long Island, New York were analyzed to determine the relationships between acidity and conductivity and concentrations of sulfate, nitrogen in nitrate plus nitrite, nitrogen in ammonium, sodium, and chloride ions. Relationships between precipitation acidity and meteorological conditions were also studied.

Hydrogen ion concentrations are similar to those elsewhere in the northeastern United States. They are best correlated with sulfate concentrations but also correlate with concentrations of nitrogen in nitrate plus nitrite and nitrogen in ammonium ion. Concentrations are highest in the summer, with cold front and squall line precipitation and with rain showers and thundershowers.

All ions measured contributed to sample conductivity but hydrogen ion contributed the most with sulfate ion second. Conductivity calculated from concentrations of the separate ions agreed well with measured conductivity. Conductivity showed relationships to meteorological conditions similar to those of hydrogen ion concentration except when sodium and chloride ions predominated in the sample.

Raynor, G.S. and J.V. Hayes, 1981: Climatology of transport and diffusion conditions along the United States Atlantic and Gulf Coasts. J. Appl. Meteorol. 20: 882-889. BNL 27728R.

ABSTRACT

A study of the atmospheric transport and diffusion climatology of the United States east and Gulf coasts was conducted to aid in planning and site selection for potentially polluting installations. This paper presents selected results from an extensive statistical study. Regular hourly observational data were obtained from thirty coastal stations from Maine to Texas and analyzed in terms of conditions important to emission transport and diffusion. The thirty stations included four pairs with one of each pair at a greater distance from the coast than the other but near the same latitude.

For each station, wind directions were classified into eight groups with reference to orientation of the local coastline. For some studies, fewer classes were desirable and these were combined into three groups--onshore, alongshore, and offshore. Wind speeds were divided into four classes. A stability class for each observation was computed by a modified Pasquill method. This gave eight classes which were combined into three--unstable, neutral, and stable--for some studies. Diffusion ratings ranging from very good to very poor were derived from combinations of wind speed and stability classes. Finally, the joint frequency distributions of wind direction and diffusion rating were calculated for each station. Data were then classified by season, time of day, wind direction, wind speed, stability class, and combinations of these variables and the percent of hours in each subgroup determined.

Onshore winds were least frequent along the New England and mid-Atlantic coasts except from Cape Cod to New York City and along the west coast of Florida. Onshore winds were most frequent along the east coast of Florida and the Texas coast. Poor diffusion conditions occurred most frequently from the Carolinas to the Florida east coast and along the northern Gulf coast. At all stations, diffusion conditions were better during the day than at night. Among the paired stations, the more inland had a greater frequency of poor diffusion hours than the one nearer the coast.

Raynor, G.S. and J.V. Hayes, 1981: Variation in chemical wet deposition with meteorological conditions. Atmos. Environ. (in press). BNL 28706R.

ABSTRACT

Analysis of hourly sequential precipitation samples collected at Brookhaven National Laboratory over a four-year period shows systematic relationships between amounts of chemicals deposited in precipitation and meteorological conditions. Samples were taken by an automatic, sequential sampler and measured for pH, conductivity, and the concentrations of major ions. Concurrent measurements and observations were made of the synoptic situation, precipitation type and rate, wind speed and direction, and temperature. Deposition per unit area was computed for subsets of the data classified by meteorological and time parameters.

Results demonstrate that precipitation amount alone is not an adequate predictor of chemical wet deposition because of the variability of concentration in precipitation which is a complex function of emission rates and atmospheric processes. Results, however, document those conditions under which most material is deposited and those circumstances in which deposition occurs at the greatest rate. When classified by season, hydrogen and sulfate ion deposition are greatest in the summer when precipitation is lowest and least in the winter when precipitation is greatest. Nitrogen in both nitrate and ammonium has a similar but less extreme pattern. By synoptic type, all chemicals are deposited most heavily in warm front precipitation but the fraction of hydrogen and sulfate deposited in cold front and squall line hours is greater than the fraction of precipitation. All chemicals are deposited most heavily in steady rain when examined by precipitation type but thundershowers deposit chemicals of anthropogenic origin in amounts disproportionate to precipitation amounts. Results are also presented from data classified by other parameters.

Raynor, G.S. and J.V. Hayes, 1981: Concentrations of some ionic species in central Long Island, New York, precipitation in relation to meteorological variables. Water, Air, and Soil Pollution (in press). BNL 29318R.

ABSTRACT

Three years of hourly sequential precipitation data from central Long Island, New York were analyzed to determine the concentrations of major anions and cations and their relationships to each other and to meteorological conditions. Findings with respect to sulfate, nitrogen in nitrate plus nitrite, nitrogen in ammonium, chloride and sodium ions and selected ratios are reported here.

Concentrations of each of the first three species were highly correlated with concentrations of the others and with hydrogen ions. Little correlation was found between these species and either sodium or chloride ions but the latter two were highly correlated with each other.

Concentrations of the first three species are highest in summer and lowest in winter. High concentrations were also found with cold front and squall line precipitation and with rain showers and thundershowers.

Concentrations of these species are high with both low and high precipitation rates. Concentrations are highest with west and northwest winds due to the presence of major source regions in those directions. They are high with both low and high temperatures but lower in the moderate temperature range. Concentrations are high with low (3.0-3.9) and with high (6.0-6.9) pH but less at intermediate levels. Thus, concentrations of these species in precipitation are determined by complex chemical and meteorological interactions and relationships.

Chloride and sodium were found to be largely of marine origin. Highest concentrations occur in the fall and with hurricanes, strong winds, and onshore wind directions. Concentrations decrease with increasing precipitation rate. At low concentrations, the chloride/sodium ratio is above the seawater ratio and excess chloride is present. At high concentrations the ratio is below the seawater ratio and a chloride deficit exists.

Raynor, G.S. and J.V. Hayes, 1981: Effects of varying air trajectories on spatial and temporal precipitation chemistry patterns. Water, Air, and Soil Pollution (in press). BNL 29623.

ABSTRACT

This study was designed to determine if judicious use of synoptic data and an operational trajectory model could identify probable source regions of anthropogenic pollutants in northeastern United States precipitation and thus relate receptor measurements to emissions data without consideration of the complex intervening meteorological and chemical processes. The storm event of April 8 to 10, 1979, was selected for intensive study. Precipitation chemistry data were obtained from event samples at six MAP3S sampling sites and from hourly samples at Brookhaven National Laboratory. Concentrations of hydrogen, sulfate, nitrate, and ammonium ions were used as receptor data. Some emissions data for SO_x and NO_x were obtained from the MAP3S emissions inventory. Surface and upper air meteorological data were analyzed. Backward trajectories ending at each of the sampling sites during the precipitation period were computed with the Heffter Interactive-Terminal Transport Model using selected transport layers.

Results show that concentrations of pollutant species in event precipitation samples were much higher at stations at end points of trajectories passing through the Ohio River Valley than at stations with other trajectories. Likewise, concentrations at Brookhaven were much higher during the end period of a trajectory through the same region than with more northerly and more southerly tracks. The model produced back trajectories consistent with synoptic flows. Concentrations of air pollutants in precipitation were roughly proportional to the number of major pollutant sources along the trajectory. These results suggest that a larger number of studies might identify more restricted source areas or even establish a quantitative relationship between source emissions along a trajectory and concentrations in precipitation at receptor sites.

Raynor, G.S., P. Michael and S. SethuRaman, 1980: Meteorological measurement methods and diffusion models for use at coastal nuclear reactor sites. Nuclear Safety 21: 749-765. BNL 27095.

ABSTRACT

A study, based on a literature review, was made to examine currently recommended meteorological measurement programs and diffusion prediction methods for nuclear power plants to determine their adequacy for plants located in coastal zones. Although procedures for handling the "near-worst" case (stable, light-wind situation) were judged adequately conservative, deficiencies in guidelines and procedures were found with respect to the following: failure to consider the role of coastal internal boundary layers, specifications for tower locations and instrument heights, methods of classifying atmospheric stability, methods of allowing credit for plume meander, and models specified for diffusion calculations. Recommendations were made for changes in the guidelines applicable to these topics. Areas in which additional research is needed were identified.

SethuRaman, S., 1981: Carbon dioxide fluxes over the Atlantic Ocean estimated from measurements at Tiana Beach, Long Island, New York. Boundary-Layer Meteorol. 20: 19-26. BNL 27305.

ABSTRACT

Mean carbon dioxide concentration gradients were measured continuously for a period of three weeks during December 1978 at Tiana Beach, Long Island, with onshore atmospheric flows. The height interval was 20 m and the fetch over the sandy beach for onshore flows was about 20 m for low tides and near zero for high tides. Measurements at the beach were thus approximately representative of over-ocean atmospheric flows. Concentration differences for this height interval were found to vary from 0.75 to 2 ppm. Approximate computations indicated this local gradient to be about two orders of magnitude greater than the values estimated from global means.

SethuRaman, S., P. Michael, W.A. Tuthill, and J. McNeil, 1980: An observation system used to study the marine boundary layer over Bay of Bengal during Summer MONEX 79. Bull. Am. Meteor. Soc. 61: 1204-1211. BNL 28453.

ABSTRACT

An observation system used to study the marine boundary layer over the Bay of Bengal at Digha Beach, West Bengal, India as part of the international Monsoon Experiments (MONEX 79) is described in this paper. It was a portable system designed to facilitate ease in transportation, quick to assemble and be independent and self sufficient in power supply and operate in remote sites for long periods of time. The experiments consisted of measurements of atmospheric turbulence, and fluxes of momentum, heat and water vapor from a 10-m-high coastal meteorological tower. Mean meteorological parameters were measured with an automated electronic weather station. Wind speed and direction profiles in the planetary boundary layer were obtained with pilot balloon soundings.

SethuRaman, S., C. Nagle, and G.S. Raynor, 1981: Seasonal variations in the formation of internal gravity waves at a coastal site. J. Applied Meteorol. (in press). BNL 29471.

ABSTRACT

Atmospheric internal gravity waves that formed over a coastal and an inland site were identified from analog records of wind speed and direction. Internal gravity waves occurred at all hours at the coastal site but only during nights inland. More waves formed during the spring and summer at the coastal site as compared to other seasons. The frequency distribution of internal gravity waves inland showed no preference in season.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

REPORTS

Benkovitz, C., 1980: MAP3S/RAINE Emissions Inventory Progress Report. BNL 51378, December 1980.

ABSTRACT

The goal of phase I of the Multistate Atmospheric Power Production Pollution Study (MAP3S) program was to develop and demonstrate an improved, verified capability of numerically simulating the present conditions and potential changes in pollutant concentration, atmospheric behavior and precipitation chemistry that result, or will result, from pollutants released to the atmosphere by large-scale power production processes. The program was divided into ten major tasks. Tasks 1 and 2 of the MAP3S program plan were concerned with the quantification of emissions of pollutants from power production and non-power production sources. These tasks have been continued under MAP3S/RAINE. The emissions inventory project has been based on obtaining pertinent data gathered by other agencies (EPA, FPC, state and local governments, etc.), and computerizing, correlating, and updating such data. This report describes the development of the project to date. Topics covered include the acquisition of both emissions and ancillary data, techniques developed for quality assurance and data updating, summaries of the data in the inventory, and descriptions of current and future plans in both upgrading and using the inventory.

Benkovitz, C.M. and V.A. Evans, 1981: User access to the MAP3S source emissions inventory. BNL 29322, March 1981.

ABSTRACT

An emissions inventory of the five criteria pollutants for the U.S. and Canada based on data obtained from NEDS, FPC, Environment Canada and other agencies has been compiled by the MAP3S Central Data Coordination at Brookhaven National Laboratory. Pertinent data was brought together, collated, and loaded into computerized data bases using SYSTEM 2000 as the data base management system. These data bases are available to interested users for interactive scanning or batch retrieval. This report provides a detailed description of the computerized data bases and details the procedures that have been implemented to allow users direct access.

Brown, R.M. and J.L. Tichler, 1981: Recommendations for portable supplemental meteorological instrumentation for incident response. BNL-NUREG 51295, NUREG/CR-1954, March 1981.

ABSTRACT

The Nuclear Regulatory Commission (NRC) staff requested technical assistance in recommending portable supplementary meteorological instrumentation which can be deployed to nuclear power plant sites in response to incidents. A supplementary meteorological system (SMS), whose primary function is to collect, analyze and disseminate supplemental meteorological information, is recommended. Instrument specifications are discussed along with maintenance and staffing requirements. A cost evaluation of the components is made.

Kleinman, L.I., 1981: Concentration and deposition of sulfur oxides in the northeastern United States: a comparison of AIRSOX model results with monitoring data for July 1978. BNL 29855, July 1981.

ABSTRACT

Atmospheric concentrations of sulfur dioxide and sulfate and wet deposition of total sulfur have been calculated for July 1978 in the eastern U.S. and adjoining Canadian areas using the Brookhaven National Laboratory long-range transport model, AIRSOX (Atmospheric Impact of Residual Sulfur Oxide). Air concentrations have been compared with the observed values of SO_2 and SO_4 at stations of the SURE network. Wet deposition of sulfur has been compared with measurements made at the MAP3S precipitation chemistry stations. Spatially averaged calculated quantities are in excellent agreement with the corresponding spatially averaged observations. The agreement between the spatial patterns of pollutants is variable. Sulfate, because it is slowly formed in the atmosphere, does not show sharp spatial fluctuations and is easier to model than SO_2. The differences between the calculated and observed SO_4 patterns exist as broad areas of over- or under-prediction. The predicted SO_2 concentration field shows a great deal more structure than the observed field. The limited number of rain events and the limited number of precipitation chemistry monitoring sites makes it difficult to draw any conclusions regarding the spatial distribution of wet deposition.

Levin, A., 1981: On the description of the turbulent fragmentation of a puff in the turbulent flow with the large Reynold's numbers. BNL 51385, March 1981.

ABSTRACT

This report is devoted to the analysis and description of the turbulent diffusion of a puff, concerning the selectively "fine" structure of the distribution of the contaminant inside such a puff. This analysis can be useful for considering the process of fast, turbulent-diffusion-controlled chemical reaction of the puff of contaminant with the surrounding chemically active medium.

Levin, A., 1981: Remarks on the description of the statistical features of the turbulent diffusion of a puff. BNL 51386, March 1981.

ABSTRACT

The process of turbulent diffusion of a puff is treated statistically through the application of Markovian random processes. A theoretical model of the fluctuations of the sizes of puffs in the inertial and outer subranges of turbulence is developed. This model is applied to explain two physical effects of turbulent diffusion.

The first is the statistical distribution of the concentration of contaminants, which is often found to be close to a lognormal distribution and the second is the growth with time of the vertical diameter of a puff in the outer subrange, which has been observed to be close to linear.

Lipfert, F.W. and L.I. Kleinman, 1981: The influence of solar energy deployment on long-range transport air pollution. BNL 51350, July 1981.

ABSTRACT

An analysis of the effects on ambient sulfur oxides of widespread deployment of various solar energy technologies by the year 2000 has been made, using the BNL long-range transport model AIRSOX. The solar energy deployment scenario was based on the Domestic Policy Review (National Energy Plan II), as supplied by the MITRE Corporation as part of the Technology Assessment of Solar Energy (TASE) project. The resulting changes in SO_x are in general quite modest (< 10%), which is a direct result of the modest changes in SO_2 emissions resulting from solar energy use. The changes over time from 1975 to 2000 are in general more important, and imply that a solar energy scenario specificially intended to optimize air quality might result in larger benefits.

Meyers, R.E., L.I. Kleinman, Ta-Yung Li, and R.T. Cederwall, 1981: Regional Issue Identification and Assessment program (RIIA) Issue Paper 2, atmospheric long-range transport lead laboratory methodology. BNL 51289, UC13, TIC-4500, March 1981.

ABSTRACT

The Brookhaven National Laboratory long-range transport air quality model, Atmospheric Impact of Residual SO_x (AIRSOX) has been used to predict sulfur dioxide and sulfate concentrations due to utility and industrial emissions, for the 1978 Energy Information Administration (EIA) Mid-Mid scenario of energy supply and demand for the years 1985 and 1990.

The results of the air quality calculations are presented for the ten Federal Regions according to fuel type and source type. The corresponding calculations have also been performed for a base case year, 1975, and the results compared with measurements. Partly because of the emission control levels assumed in the EIA scenario, SO_2 emissions in 1985 and 1990 are lower than in 1975 despite increases in fuel consumption and a shift from oil to coal in the utility and industrial sectors. National average sulfur oxide concentrations are calculated to be lower in 1985 and 1990 than in 1975.

Raynor, G.S., J.V. Hayes, and D.M. Lewis, 1981: Testing of the ARL-ATAD trajectory model on cases of particle wet deposition after long-distance transport from known source regions. BNL 29702.

ABSTRACT

The Heffter Interactive-Terminal Transport Model was tested to determine how well it could identify probable pathways and source regions of airborne pollens from non-local sources which were deposited in precipitation at Albany, New York. This model is a version of the Air Resources Laboratories Atmospheric Transport and Dispersion Model programmed to run on the Brookhaven National Laboratory computer. The model calculates trajectories of three days' duration either forward or backward in time from any selected location starting every six hours during a chosen time period. Each trajectory is calculated using transport winds averaged over a selected vertical layer. Calculations are based on past upper air observations stored in the computer.

At Albany, New York, airborne pollens were sampled by horizontal sheets of sticky paper during both wet and dry weather and also in jars during precipitation. Pollens were separated from the liquid by filtration. Representative samples of the filters and the sticky paper were examined under a microscope and pollen grains identified and counted. In this study, only obviously fresh pollens of non-local origin are considered. These were obtained primarily in the winter and early spring months before local pollens of the same or similar species were released and include species whose ranges do not reach the northeastern states. These cases document atmospheric transport from distant source regions and subsequent wet deposition.

Probable source regions were determined from ranges and flowering dates of the species collected. Backward trajectories from Albany were computed for nine precipitation events. In all cases, the trajectories passed through or very near previously selected source regions located to the south or southwest. Travel times ranged from 10 to over 50 hours but were mostly from 18 to 42 hours. Results demonstrate the utility of the model and the feasibility of locating sources of materials transported over long distances.

Tichler, J. and C. Benkovitz, 1981: Radioactive materials released from nuclear power plants. Annual Report 1978. BNL-NUREG 51192, NUREG-CR-1497, March 1981.

ABSTRACT

Releases of radioactive materials in airborne and liquid effluents from commercial light water reactors during 1978 have been compiled and reported. Data on solid waste shipments as well as selected operating information have been included. This report supplements earlier annual reports issued by the former Atomic Energy Commission and the Nuclear Regulatory Commission. The 1978 release data are compared with previous years' releases in tabular form. Data covering specific radionuclides are summarized.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

MEETING PRESENTATIONS AND PROCEEDINGS

Benkovitz, C.M., 1981: Compilation of source emissions data and their use in air quality models. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. To appear in the Preprint Volume. BNL 30101.

ABSTRACT

Accurate, comprehensive data on the sources of materials being released into the atmosphere are essential to any program whose goals include the evaluation and verification of numerical models of air quality. Formats suitable for the compilation of emissions data are usually not suitable for their use as model input. The approximations and transformations to be applied to these data have become an important part of model development.

This paper describes how some of these topics are being studied as part of the Central Data Coordination project of the MAP3S program. Among topics included in this paper are development of the current MAP3S Emissions Inventory, data summaries created to characterize current emissions, definition of problem areas encountered in the use of these data as model input, as well as some of the solutions being developed.

Evans, V., 1981: A comparison of System-2000 and Scientific Information Retrieval (SIR) in a specific scientific application. Presented at the ASTUTE Spring Conference, Austin, TX, March 25, 1981. BNL 29228.

ABSTRACT

A System-2000 data base had been implemented in analyzing acid rain data. For this paper a SIR data base was created using the same data, and a comparison was made of the two DBMS. Special attention was given to the cost, length of time, and computer resources used in loading, storing, updating, and retrieving data. The advantages of S2K were its English-like language, its efficient storage of data on disk, and its modification process. The advantages of SIR were its data loading process, its efficient data retrieval process, and the availability of a wide range of scientific functions for analysis of data.

Lipfert, F.W., P.M. Meier, and L.I. Kleinman, 1981: Regional analysis of energy facility siting. Presented at SOGESTA Workshop on Energy Policy Analysis, Urbino, Italy, November 3-6, 1980. BNL 29324.

ABSTRACT

In the United States and many of the industrialized countries, virtually no new energy facility can be proposed for a given region without eliciting controversy over both economic and environmental issues. These issues often include tax and employment benefits, worker housing, and local environmental impacts. In the United States, many of these rather obvious issues are highly institutionalized, and thus are dealt with through regulations, siting authorities, and planning commissions.

The regional contexts are often more subtle and thus overlooked. Industrial development in a region often feeds upon itself, and thus acts as a magnet to adjacent, less developed regions, creating migration, urbanization, and often the social ills that may accompany these facets of development. Environmentally, both air and water pollution may be transported beyond political boundaries, with effects beyond the control of the recipients. Analytical methods are now available to deal with these effects, and it remains for planning bodies to recognize these aspects of facility siting and to deal with them accordingly. This analysis, which draws heavily on previous methodological developments, shows that such recognition may be considerably easier than the formulation of siting policies that will negate the inevitable controversies.

Michael, P. and G.S. Raynor, 1981: Modifications of trajectory models needed for pollutant source-receptor analysis. Presented at the NATO/CCMS 12th International Technical Meeting on Air Pollution Modeling and its Applications, Palo Alto, CA, August 25-28, 1981. Preprint Volume, pp. 249-258 (Hosted by SRI International; Committee on Challenges of Modern Society, NATO). BNL 29924.

ABSTRACT

An important application of trajectory models is the identification of air pollutant source regions that impact upon specific sensitive areas. One such application of current interest is identification of sources responsible for delivering pollutants to precipitation so that strategies to mitigate the effects of acid rain may be evaluated. An examination of the data from a number of events in which the chemical composition of precipitation has been measured has indicated that modifications to the usual trajectory model method in which winds are averaged over a mixed layer are required. If the precipitation is from a frontal storm the three-dimensional trajectory of the overrunning air from the warm sector must be calculated in order to estimate the delivery of pollutants to clouds (input to the "rainout" process); on the other hand, below-cloud scavenging ("washout") will depend upon trajectories in the cold air preceding the front. Trajectory calculations that cover more than a single diurnal cycle can mis-identify source regions if they do not account for the fact that day-to-day variations in the height of the mixed layer can create layers of pollutant that move on different trajectories. Recommendations for model modifications are presented.

Patrinos, A.A.N. and M.J. Leach, 1981: On the use of the pseudo-spectral technique in air pollution modeling. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. To appear in the Preprint Volume. BNL 30033.

ABSTRACT

Two serious drawbacks of the pseudo-spectral approach to air pollution modeling are addressed and some improvements and remedies are suggested. Chosen primarily for its low numerical diffusion, the pseudo-spectral technique requires periodic boundary conditions leading to unrealistic physical situations. Instead of using "absorbing layers" we have accommodated this requirement with a suitable coordinate transformation (the arctan function) which also allows a greater coverage in physical space with variable resolution. The second drawback, the aliasing error, is usually handled by filtering the high frequency oscillations. Filtering, however, disturbs the conservative property of the computations and some remedies are proposed.

Raynor, G.S., 1981: Design and preliminary results of the Intermediate Density Precipitation Chemistry Experiment. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. To appear in the Preprint Volume. BNL 29992.

ABSTRACT

The Intermediate Density Precipitation Chemistry Experiment was conducted in April 1981 as one of two concurrent components of the interlaboratory OSCAR (Oxidation and Scavenging Characterization of April Rain) experiment under the MAP3S/RAINE (Multistate Atmospheric Power Production Pollution Study/Regional Acidity of Industrial Emissions) program. The purpose of the experiment was to sample several rain events with fine temporal and moderate spatial resolution while making maximum use of precipitation collection stations established earlier under the MAP3S program and by other cooperating agencies.

Thirty-seven existing and temporary sampling sites were operated from Illinois to New Hampshire and from southern Ontario to Tennessee and North Carolina. Most stations were spaced from 100 to 200 km apart, intermediate between the MAP3S network with 400 to 1100 km spacing and an intensive OSCAR network in Indiana with about 14 km spacing. All except two which used automatic sequential samplers were equipped with manually operated funnel and bottle collectors on elevated stands. Bottles were changed each time about 100 ml (0.6 mm) of rain was collected. Sample times ranged from two minutes to an hour or more depending on the rainfall rate and were recorded to the nearest minute. Several thousand samples were taken in three rain events. The weight and pH of each sample were measured soon after collection. The samples were then sent to an analytical laboratory for measurement of all major ions.

A forecast center was operated at Brookhaven National Laboratory to select events for sampling and to advise stations of approaching rain. Air and cloud water chemistry were measured during each event by three research aircraft. Near ground-level air chemistry was measured at two sites and available monitoring data are being obtained from stations in the experimental region. Complete meteorological data were obtained for each event and archived. All information is being entered in a computer data bank.

The data will be used for many purposes including evaluation of the optimal spacing of precipitation sampling stations, documentation of the amount of temporal and spatial variability in precipitation chemistry during representative events, investigating of relationships between air chemistry and precipitation chemistry and between precipitation chemistry and meteorological conditions, relating pollutants in precipitation to probable source regions and inferring mechanisms by which pollutants are incorporated into cloud droplets and deposited by precipitation. Pending the availability of complete measurements, preliminary results based on field pH measurements will be presented.

Raynor, G.S. and J.V. Hayes, 1981: Relationships of chemical wet deposition to precipitation amount and meteorological conditions. Presented at the 181st National Meeting of the American Chemical Society, Environmental Chemistry Division, Atlanta, GA, March 29-April 3, 1981. To appear in the Proceedings. BNL 29434.

ABSTRACT

Analysis of hourly sequential precipitation samples collected at Brookhaven National Laboratory over a four-year period shows systematic relationships between amounts of materials deposited in precipitation and meteorological conditions. Samples were taken by an automatic sequential sampler and analyzed for pH, conductivity and concentrations of sulfate, nitrogen in nitrate plus nitrite, nitrogen in ammonium, sodium, and chloride. Concurrent measurements and observations were made of synoptic situation, precipitation type and rate, wind speed and direction and temperature. Deposition per unit area was computed for subsets of the data classified by meteorological and time parameters and compared with precipitation amounts in the same subset. Data are presented as percentage deviations from the amounts that would be expected if chemical wet deposition were proportional to precipitation amount.

Results demonstrate that chemical wet deposition is a function of concentration in the precipitation as well as precipitation amount. When classified by season, deviation of hydrogen and sulfate ion deposition is most positive in the summer when precipitation is lowest and most negative in the winter when precipitation is greatest. Nitrogen in nitrate plus nitrite and in ammonium has a similar but less extreme deposition pattern. In contrast, chloride and sodium deviations are most positive in the fall and most negative in the summer. By synoptic type, hydrogen and sulfate ion deviations are positive with cold front and squall line cases and negative with warm front precipitation. By precipitation type, the same species are strongly positive in thundershowers and negative in rain. Results are also presented for other species and other meteorological and time classifications.

Raynor, G.S. and J.V. Hayes, 1981: A case study of meteorological and synoptic methods for estimating source regions of chemicals in precipitation. Presented at AMS/CMOS Conference on Long-Range Transport of Airborne Pollutants, Albany, NY, April 27-May 1, 1981. Abstract BNL 28624.

ABSTRACT

Much information has been obtained in recent years on the chemical constituents of precipitation in the northeastern United States and on their temporal and spatial variability. Inventories are available which give emission rates and locations for major air pollutant sources. However, few attempts have been made to identify sources or even general source regions of contaminants in precipitation. This is due, in part, to the complexities of the atmospheric motions, cloud and rain formation mechanisms and chemical reactions which occur during pollutant transport from source to receptor and to the lack, until recently, of precipitation chemistry data with adequate spatial coverage and temporal resolution. This study was designed to test available methods for relating precipitation chemistry to source emissions. The methods are described, problems and uncertainties discussed, and the results of an intensive case study presented.

The precipitation event of 8-10 April 1979 was chosen for the study. Precipitation chemistry data were obtained from event samples at seven MAP3S sites and hourly samples at Brookhaven National Laboratory. The distribution of major emission sources was determined. Surface and upper air synoptic data and radiosonde data for the three-day period were analyzed. Three-day back trajectories ending at each sampling site at six-hour intervals were calculated using the Heffter Interactive-Terminal Transport Model over selected height intervals.

Results show good relationships between air trajectories and concentrations at sampling sites. Stations sampling precipitation in air which passed over known major source regions found higher concentrations of anthropogenic pollutants than stations on trajectories not passing over such regions. Short period changes in precipitation chemistry at Brookhaven National Laboratory were clearly related to changing trajectories of the air reaching the site.

Raynor, G.S. and J.V. Hayes, 1981: Applications of within-event precipitation chemistry measurements. Presented at the ASTM Symposium and Workshop on Sampling and Analysis of Rain, Philadelphia, PA, October 7, 1981. To appear in special technical publication of the symposium. BNL 29879.

ABSTRACT

Chemical measurements from hourly sequential precipitation samples and simultaneous meteorological measurements and observations were analyzed to discover relationships between chemical species, to infer atmospheric mechanisms, to relate precipitation chemistry to meteorological events and conditions, and to identify probable pollutant source regions. Analytical methods that can be applied to short-period samples but usually not to event, weekly, or monthly samples are described and illustrated.

Changes in concentrations of chemical species during precipitation events can be documented and used to infer atmospheric processes. These changes can also be related to meteorological conditions such as changes in rainfall rate and wind direction or to frontal passages. Source directions and probable source regions can be located by wind direction and trajectory analyses. Means of many samples taken under similar conditions can document relationships between meteorological conditions, concentrations in precipitation and amounts of wet deposition.

Raynor, G.S., J.V. Hayes, and D.M. Lewis, 1981: Trajectory analysis of wet and dry deposited pollens from distant sources. Presented at the 15th Conference on Agriculture and Forest Meteorology and Fifth Conference on Biometeorology, Anaheim, CA, March 30-April 3, 1981. BNL 28980.

ABSTRACT

The Heffter Interactive-Terminal Transport Model was tested to determine how well it could identify probable pathways and possible source regions of airborne pollens from non-local sources, which were deposited in precipitation and during dry weather in Albany, N.Y. This model is a version of the Air Resources Laboratories Atmospheric Transport and Dispersion Model programmed to run on the Brookhaven National Laboratory computer. The model calculates trajectories of 3-days duration either forward or backward in time from any selected location starting every 6 hours during a chosen time period. Each trajectory is calculated using transport winds averaged over a selected vertical layer. Calculations are based on past meteorological upper air observations stored in the computer.

In Albany, N.Y., airborne pollens were sampled by horizontal sheets of sticky paper during both wet and dry weather and also in jars during precipitation. Pollens were separated from the liquid by filtration. Representative samples of the filters and the sticky paper were examined under a microscope, and pollen grains were identified and counted. In this study, only obviously fresh pollens of non-local origin are considered. These were obtained primarily in the winter and early spring months before local pollens of the same or similar species were released. Pollen of species whose ranges do not include the northeastern states were also obtained. This documents aerial transport from distant source regions and subsequent washout or deposition.

Possible source regions were determined from ranges and flowering dates of the species collected. Backward trajectories from Albany were computed for the most probable transport layers. These trajectories generally passed through possible source regions that were usually to the south or southwest 2 or 3 days before the date of sampling at Albany, thus demonstrating the general validity of the model calculations.

SethuRaman, S., 1980: Marine boundary layer wind structure over Bay of Bengal during Indian southwest monsoon. Presented at 13th Amer. Meteor. Soc. Technical Conference on Hurricanes and Tropical Meteorology, Coral Gables, Fla., Dec. 5, 1980. Abstract BNL 28260.

ABSTRACT

A marine boundary layer experiment was conducted over Bay of Bengal, at West Bengal, as part of the International Monsoon Experiments (MONEX-79). Atmospheric turbulence, and fluxes of momentum, heat and water vapour were measured from a 10-m-high coastal meteorological tower. Wind speed and direction profiles in the boundary layer were obtained with pilot balloon soundings. Near-surface mean wind speed, direction, air temperature, dew point, solar radiation, and precipitation were measured for 30 days. Results regarding the structure of the marine boundary layer indicate a jet-like flow pattern associated with the monsoon flow over the Bay of Bengal.

SethuRaman, S., 1981: Marine boundary layer wind structure over the Bay of Bengal during MONEX79. Presented at International Symp. on Early Results of FGGE-MONEX Experiments, Tallahassee, FL, January 12-17, 1981. WMO GARP Report 41-47. BNL 29724.

ABSTRACT

A marine boundary layer experiment was conducted over Bay of Bengal, at West Bengal, as part of the International Monsoon Experiments (MONEX-79). Atmospheric turbulence, and fluxes of momentum, heat and water vapour were measured from a 10-m-high coastal meteorological tower. Wind speed and direction profiles in the boundary layer were obtained with pilot balloon soundings. Near-surface mean wind speed, direction, air temperature, dew point, solar radiation, and precipitation were measured for 30 days. Results regarding the structure of the marine boundary layer indicate a jet-like flow pattern associated with the monsoon flow over the Bay of Bengal.

SethuRaman, S., 1981: Dynamics of the atmospheric boundary layer during the 1980 total solar eclipse. Presented at the International Symposium on February 16, 1980 Solar Eclipse, Indian National Science Academy, New Delhi, India, January 27-31, 1981. BNL 29497.

ABSTRACT

An atmospheric boundary layer experiment was conducted at Raichur, India to study the variations in the surface shear stress, heat flux and the meteorological processes that take place during a total solar eclipse. Interesting results were observed regarding the evolution of the planetary boundary layer. Changes in atmospheric stability from unstable to stable to unstable were observed during different phases of the eclipse. Downward propagation of negative heat flux associated with decreasing scales of convective eddies was also observed during the eclipse.

SethuRaman, S., 1981: Wave induced variations in the marine boundary layer turbulence and momentum flux. Presented Symposium on Wave Dynamics and Radio Probing of the Ocean Surface, Miami Beach, FL, May 13-20, 1981. To appear in the Proceedings. Abstract BNL 28741.

ABSTRACT

Two air-sea interaction experiments were conducted in the Atlantic Ocean off Long Island at distances of 5 km and 15 km, respectively, from the shore during 1977 and 1979. One of the objectives of the experiments was to study the variations in the turbulence and the momentum and heat fluxes in the marine surface layer due to changes in the surface wave characteristics. In order to accomplish this purpose, measurements of the turbulence, fluxes and wave heights were carried out continuously for several weeks for each experiment.

The purpose of this paper is to present results of these experiments pertaining to atmosphere-wave interactions. Time history of momentum flux into the ocean indicates reversal or upward flux immediately after abrupt changes in wave propagation direction. Magnitudes of these upward fluxes and the transitions in relation to the meteorological and surface wave parameters will be discussed. These upward fluxes occur often enough to be of importance and should be considered in developing algorithms for the remote sensing of surface winds over oceans. Atmospheric turbulence induced by the waves will also be discussed and explained in terms of partially and fully developed waves.

SethuRaman, S., 1981: Interaction of the atmospheric boundary layer with large-scale processes over the Bay of Bengal during summer MONEX79. Presented at the International Conference on Scientific Results of the Monsoon Experiments, Denpasar, Bali, Indonesia, October 26-30, 1981. To appear in the Proceedings. Abstract BNL 29722.

ABSTRACT

An atmospheric boundary layer experiment was conducted at the coast of the Bay of Bengal at Digha, West Bengal, India, during the Summer MONEX79. Onshore winds associated with the Indian southwesterly monsoon existed at the experimental site for about 95 percent of the observational period. Results indicate a strong interaction between the structure of the marine boundary layer over the Bay of Bengal and the large-scale processes such as the orientation of the monsoon trough and the cylogenesis over Bay of Bengal.

Wind profiles in the boundary layer obtained from pilot balloon observations indicated the presence of a strongly stable layer with jet-like flow in the boundary layer to heights of about 600 m. This feature occurred in about 70 percent of the observations during the four-week experiment. The other 30 percent indicated uniform wind structure up to 1000 m, representative of convective boundary layer. In both cases, surface layer turbulence measurements indicated upward heat flux. There appears to be a significant correlation between the location of the monsoon trough and the marine boundary layer wind structure over the Bay of Bengal. When the trough is far north at the foothills of the Himalayas, the boundary layer seems to consist of a shallow convective layer (~ 50 m) capped with a strong stable layer. This type of structure would cause a discontinuity in the heat flux in a vertical plane and inhibit cyclogenesis. A more uniform convective boundary layer as indicated by the lack of jet-like feature in the wind profiles was found to be associated with the trough over the Gangetic plains extending into the head of the Bay of Bengal. Quantitative values of the boundary layer parameters in support of the above hypothesis are presented.

SethuRaman, S., A. Prabhu, N. Narahari, and R. Narasimka, 1981: Atmospheric boundary layer processes during a total solar eclipse. Presented at the AMS Fifth Symposium on Turbulence, Diffusion and Air Pollution, March 9-13, 1981, Atlanta, GA. BNL 28555.

ABSTRACT

A total solar eclipse that occurred on February 16, 1980 over the southern part of India over a strip of about 120 km wide provided a unique opportunity to study the variations in the characteristics of the earth's atmospheric boundary layer when the solar radiation is diminished. The time interval between the first and fourth contact was 2 hours 30 minutes and the duration of totality at Raichur (16°12'N, 77°21'E), the experimental site, was 2 minutes and 42 seconds. First contact occurred at 1425 IST; thus a well-developed convective boundary layer was present before first contact.

The boundary layer measurements consisted of 1) a 12-m micrometeorological tower with instruments to measure longitudinal, lateral, and vertical velocity fluctuations and temperature fluctuations; 2) mean temperature profiles to a height of about 3000 m with mini-radiosondes and; 3) pilot balloon soundings of wind speed and direction. Measurements were also made for two days before the eclipse and a day after to determine the characteristics of the boundary layer that may be site dependent.

Results indicate significant changes in the structure of the boundary layer between first and second contacts. Cooling of the air was observed over the entire thickness of the boundary layer with surface-based inversion. Variations in heat flux and turbulence before, during, and after the eclipse with the associated time scales will be presented. The results on the day of the eclipse will be compared with those on other similar days to give an insight into the variations in the boundary layer processes that occurred during a total solar eclipse and into the dynamics of the evolution of the earth's planetary boundary layer.

SethuRaman, S., G.S. Raynor, and R.M. Brown, 1981: Variation of turbulence in a coastal thermal internal boundary layer. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. To appear in the Preprint Volume. BNL 30045.

ABSTRACT

Standard deviations of the vertical velocity fluctuations, σ_w, were measured with a sail plane variometer at various altitudes within a Thermal Internal Boundary Layer (TIBL) that developed over Long Island with onshore flows from the Atlantic Ocean. The observations were made from a height of about 150 m to the top of the TIBL. Results indicate the average σ_w increases with the land-water temperature difference. The position of maximum σ_w seems to vary from one experiment to another. Sharp increases in σ_w with height ($>z^{1/3}$) were observed for the sea breezes.

Shannon, J.D., L. Kleinman, C. Benkovitz, and C. Berkowitz, 1981: Intercomparison of MAP3S models of long-range transport and deposition. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, San Antonio, TX, January 11-15, 1982. To appear in the Preprint Volume.

ABSTRACT

Numerical models of long-range transport and deposition developed in the Multistate Atmospheric Power Production Pollution Study (MAP3S) are intercompared with observations and with each other. The models are ASTRAP from Argonne National Laboratory, AIRSOX from Brookhaven National Laboratory, and RAPT from Battelle Pacific Northwest Laboratory. Observation data include air quality and precipitation chemistry measurements from the SURE, MAP3S, and CANSAP networks. Intercomparisons are for July and January of 1978; the models show best agreement with the average $SO_4^=$ field; agreement with precipitation chemistry data is less satisfactory, in large part due to the convective nature of summer precipitation and the resulting spatial irregularities. Transport, transformation, and removal parameterizations are detailed in model "profiles" in order to focus on the causes of differences in simulations.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

PERSONNEL

The current staff and consultants of the Atmospheric Sciences Division are listed below. Biographies of the scientific and professional staff members follow.

Scientific and Professional Staff

Paul Michael, Division Head	Senior Physicist
Gilbert S. Raynor, Associate Division Head	Meteorologist
Carmen M. Benkovitz	Senior Environmental Science Associate
Robert M. Brown	Senior Meteorology Associate
Veronica A. Evans	Programmer/Analyst
Janet V. Hayes	Meteorology Associate II
Lawrence I. Kleinman	Chemist
Martin J. Leach	Meteorology Associate II
Aristides A. N. Patrinos	Associate Meteorologist
S. SethuRaman	Meteorologist
Joyce L. Tichler	Senior Computer Analyst

Technical Support Staff

Seymour Fink
Walter E. Jahnig
John P. McNeil

Computer Support Staff

Joan H. Glasmann
Catherine T. Henderson
Kathy J. Norden

Secretarial Support Staff

Lola E. Kopp

Consultants

Dr. Martin I. Hoffert, Associate Professor
Department of Applied Science, New York University.
Dr. Edward O'Brien, Professor
Department of Mechanics, State University of New York at Stony Brook
Dr. Arnold Levin, Private Consultant

CARMEN M. BENKOVITZ Senior Environmental Science Associate

Education	Universidad de Villaneuva, Havana, Cuba (B.S., Chemical Engineering, 1961); Columbia University (M.S., Chemical Engineering, 1967).
Research Interests	Management and Analysis of Environmental Data with Special Emphasis in Atmospheric Emissions Inventories, Air Quality and Precipitation Chemistry Data.
Professional Affiliations	American Institute of Chemical Engineers; Association for Computing Machinery; Sigma Xi.
Summary of Experience	Responsible for the management and analysis of environmental data for various programs in the Department of Energy and Environment. Principal investigator for the Central Data Coordination Project of the MultiState Atmospheric Power Production Pollution Study (MAP3S) of the Atmospheric Sciences Division, a project involving the formulation and analysis of working data sets in the areas of air quality, precipitation chemistry, and atmospheric emissions inventories. Participated as BNL representative in the InterLaboratory Working Group for Data Exchange of the Department of Energy as well as other advisory workshops on the management of scientific data (most recently the Climate Program Data Management Workshop and the EPA Working Group on the Central Precipitation Chemistry Data Bank).
Selected Publications	Benkovitz, C. M., Editor. DOE interlaboratory working group for data exchange progress report - October 1978. BNL 51071, July 1979. Benkovitz, C. M. and Heffter, J. L. User's guide to the Heffter interactive-terminal transport model (ARL-HITTM). BNL 27801, April 1980. Benkovitz, C. M. MAP3S/RAINE emissions inventory progress report. BNL 51378, December 1980. Benkovitz, C. M. Compilation of an inventory of anthropogenic emissions in the United States and Canada. Accepted for publication in Atmospheric Environment.

ROBERT M. BROWN	Senior Meteorology Associate
Education	Spartan School of Aeronautics (Diploma in Meteorology, 1947); Hofstra University (B.A., Physics, 1966).
Research Interests	Regional Air Pollution Studies; Coastal Meteorology; Meteorological Instrumentation.
Professional Affiliations	American Geophysical Union; American Meteorological Society.
Summary of Experience	Participated in many governmental experimental programs dealing with atmospheric diffusion associated with emissions from power plant stacks; responsible for meteorological instrumentation used in atmospheric diffusion studies including airborne studies involving regional air pollution undertaken by the Department of Energy and the Environmental Protection Agency in the MultiState Atmospheric Power Production Study (MAP3S) and the Northeast Region Ozone Study (NEROS - 1979 and 1980). Recent experience includes experimental studies at the land, sea, air interface off the coast of Long Island, regional scale transport and transformation experiments of airborne material and gases over selected areas in the northeast United States, developing recommendations for the Nuclear Regulatory Commission for supplementary meteorological instrumentation for incident response, and analyzing experimental data collected during NEROS 1979 and NEROS 1980.
Selected Publications	Brown, R. M., and SethuRaman, S. Temporal variation of particle scattering coefficients at Brookhaven National Laboratory, New York. Atmos. Envir. 15, No. 9, 1733-37 (1981). Brown, R. M., and Tichler, J. L. Recommendations for portable supplemental meteorological instrumentation for incident response. NUREG/CR-1954, BNL-NUREG-51295, March 1981. SethuRaman, S., Raynor, G. S., and Brown, R. M. Variation of turbulence in a coastal thermal internal boundary layer. To be presented at the Third Joint Conference on Applications of Air Pollution Meteorology, Am. Meteor. Soc., San Antonio, TX, Jan. 11-15, 1982. To appear in preprint volume. Brown, R. M., SethuRaman, S., and Nagle, C. Atmospheric stability comparisons at shore and inland sites. Presented at the Second Conference on Coastal Meteorology, Am. Meteor. Soc., Los Angeles, CA, Jan. 30-Feb. 1, 1980.

VERONICA A. EVANS	Programmer/Analyst
Education	State University of New York at Farmingdale (A.A.S., Chemical Technology, 1964); Dowling College (B.S., Mathematics, 1974).
Research Interests	Manipulation and Analysis of Data for Atmospheric Modeling; Data Management of Air Quality, Emissions, and Precipitation Chemistry Data.
Professional Affiliations	Association for Computing Machinery; Association of SYSTEM 2000 Users for Technical Exchange.
Summary of Experience	Brookhaven National Laboratory 1964-69; 1973-present. Previously involved in the chemical analysis of environmental samples for radiological content; water quality analyses of BNL's well water; performed bioassay analyses on Reactor personnel. Presently responsible for the acquisition, management, and analysis of environmental data such as emissions inventory, air quality and precipitation chemistry data. Work involves use of SIR, S2K, SPSS, and DISSPLA software systems and CDC 7600/6600 PDP11, and VAX hardware systems.
Selected Publications	Evans, V. A comparison of system 2000 and scientific information retrieval in a specific scientific application. BNL 29228, March 1981. Benkovitz, C. and Evans, V. User access to the MAP3S source emissions inventory. BNL 29322, March 1981.

JANET V. HAYES	Meteorology Associate II
Education	State University of New York at Albany (B.S., Mathematics, 1958; M.S., Biology, 1960), Suffolk County Community College (Fortran Programming).
Research Interests	Precipitation Chemistry, Coastal Meteorology and Climatology, Diffusion, Aerobiology.
Professional Affiliations	Member, Issue Inc., the International SPSS Software Users Exchange; BNL-SPSS Local Users Group and Computer Users Organization.
Summary of Experience	Responsible for the analysis of data for precipitation chemistry studies and coastal meteorology and climatology under the direction of G. S. Raynor. Co-author of publications and reports. Analysis methods include original FORTRAN programs and utilization of software packages such as SPSS, SIR, BMDP, and computer graphics. Previously (1961-73) participated in all phases of extensive pollen dispersion and sampling studies conducted by G.S. Raynor and E.C. Ogden of the New York State Museum and Science Service; studies funded by the PHS and EPA through the NYS Education Department. Prior to research activities, taught high school mathematics and college biology laboratory sessions as a Graduate Teaching Fellow.
Selected Publications	Raynor, G. S. and Hayes, J. V. Acidity and conductivity of precipitation in central Long Island, New York in relation to meteorological variables. Water, Air and Soil Pollution 15, 229-245 (1981). Raynor, G. S. and Hayes, J.V. Effects of varying air trajectories on spatial and temporal precipitation chemistry patterns. Accepted for publication in Water, Air and Soil Pollution. BNL 29623, April 1981. Raynor, G. S., Hayes, J. V., and Lewis, D. M. Testing of the ARL-ATAD trajectory model on cases of particle wet deposition after long-distance transport from known source regions. Submitted for publication. BNL 29702, 1981. Raynor, G. S. and Hayes, J. V. Climatology of transport and diffusion conditions along the United States Atlantic and Gulf Coasts. Journal of Applied Meteorology 20, 882-889 (1981).

LAWRENCE I. KLEINMAN Chemist

Education	City College of New York (B.S., Chemistry, 1967); Yale University (Ph.D., Chemistry, 1971); Postdoctoral Fellow, University of California at Irvine, 1971-73.
Research Interests	Kinetics and Transport of Atmospheric Pollutants; Turbulent Flows; Chemical Dynamics.
Professional Affiliations	American Physical Society.
Summary of Experience	Responsible for regional air quality analyses used in DOE evaluation of future energy scenarios. In this and other contexts, long-range transport models were used for the purpose of determining source-receptor relationships, stack height effects, pollutant budgets and residence times, ambient air quality, and precipitation composition. Research contributions in the fields air pollution modeling, chemical kinetics, and quantum mechanics.
Selected Publications	Lipfert, F. W. and Kleinman, L. I. The influence of solar energy deployment of long-range transport of air pollution. BNL 51350, July 1981. Kleinman, L. I. Concentration and deposition of sulfur oxides in the northeastern United States: a comparison of AIRSOX model results with monitoring data for July 1978. BNL 29855, April 1981. Kleinman, L. I., Carney, T. A., and Meyers, R. E. Time dependence of average regional sulfur oxide concentrations. Proc. AMS/APCA Second Joint Conference on Applications of Air Pollution Meteorology, New Orleans, March 1980, pp. 87-91, American Meteorological Society, 1980. Kleinman, L. I., Cederwall, R. T., and Meyers, R. E. Modeling sulfur oxide concentrations: an assessment of energy utilization scenarios. Proc. Sixth National Conference on Energy and Environment, Pittsburgh, May 1979, D. G. Nichols, R. A. Servais, E. J. Rolinski, Editors, pp. 85-92, American Institute of Chemical Engineers, Dayton, 1979.

MARTIN J. LEACH — Meteorology Associate II

Education — St. Joseph's College, PA (B.S., Physics, 1971); St. Louis University (Meteorology, 1971-72); Drexel University (M.S., Physics and Atmospheric Sciences, 1975).

Research Interests — Eulerian and Lagrangian modeling of atmospheric transport processes with special application to air pollution and air chemistry; synoptic meteorology and weather forecasting.

Summary of Experience — Served as a weather forecaster in the U.S. Air Force. Assisted in the development of a large numerical code to forecast the development of mesoscale systems in the atmosphere, including cloud and precipitation processes. Also worked with verification of the model output.

Selected Publications

Leach, M. J. Tests using a sequential plume cumulus model for forecasting convective precipitation, Proc. 6th Conference on Weather Forecasting and Analysis, American Meteor. Society, Albany, May 1976, pp. 221-2, American Meteorological Society, 1976.

Kreitzberg, C. W., Leach, M. J., and Rasmussen, R. G. Convective precipitation prediction tests using cumulus model. Final Report, Techniques and Development Laboratory, No. 5-35361, Drexel University, 1978.

Kreitzberg, C. W. and Leach, M. J. Diagnosis and prediction of tropospheric trajectories and cleansing. Presented at the 85th Annual Meeting of the AIChE, Philadelphia, PA, June 1978.

Patrinos, A. A. N. and Leach, M. J. On the use of the pseudo-spectral technique in air pollution modeling. For presentation at the Third Joint Conference on Applications of Air Pollution Meteorology, January 11-15, 1982, San Antonio, TX. To appear in preprint volume.

PAUL A. MICHAEL	Senior Physicist
Education	New York University (A.B., Physics, 1949; Ph.D., Physics, 1959); University of Chicago (M.S., Physics, 1955).
Research Interests	Atmospheric Transport of Air Pollutants; Mathematical Modeling; Micrometeorology.
Professional Affiliations	American Meteorological Society; American Physical Society; American Nuclear Society.
Committees	Director of the interlaboratory MultiState Atmospheric Power Production Pollution Studies; Member AMS Committee on Meteorological Aspects of Air Pollution; Member, Computer Policy Advisory Committee, BNL; Past Member and Chairman, Reactor Safety and Critical Experiments Safety Committee.
Summary of Experience	Responsible for directing the research within the Atmospheric Sciences Division. The major research areas are the MultiState Power Production Pollution Study (MAP3S) which is investigating the long-range transport of air pollutants, and the Planetary Boundary Studies at the Land-Sea Interface, which is aimed at improving the prediction of diffusion in the coastal zone. Within the MAP3S program, serves as the interlaboratory Program Director and coordinator for numerical modeling. Past experience includes research in fluid dynamics, neutron physics, and reactor physics.
Selected Publications	Raynor, G. S., Michael, P. A., and SethuRaman, S. Meteorological measurement methods and diffusion models for use at coastal nuclear reactor sites. Nucl. Saf. 21, No. 6, 749-65 (1980). Michael, P., Hoffert, M., Tobias, M., Tichler, J. Transient climate response to changing carbon dioxide concentration. Climatic Change 3, No. 2, 137-153 (1981). Michael, P., and Raynor, G. S. Modifications of trajectory models needed for pollutant source-receptor analysis. Presented at the NATO/CCMS 12th International Tech. Meeting on Air Pollution Modeling and its Applications, Palo Alto, CA, August 25-28, 1981. Preprint Volume, pp. 249-258. To appear in the Proceedings. Michael, P., Editor. MAP3S/RAINE modeling abstracts, 1980, BNL Formal Report 51247, July 1980.

ARISTIDES A.N. PATRINOS Associate Meteorologist

Education	National Technical University of Athens, Greece (Diploma, Mechanical and Electrical Engineering, 1970); Northwestern University (Ph.D., Mechanical Engineering and Astronautical Sciences, 1975).
Research Interests	Geophysical Fluid Dynamics; Numerical Solutions of Partial Differential Equations; Inadvertent Weather Modification.
Professional Affiliations	American Society of Mechanical Engineers; American Meteorological Society; Greek Technical Society.
Summary of Experience	Technical consultant to the Argonne National Laboratory on heat exchanger flows (1975). Assistant Professor at Department of Mechanical and Aerospace Sciences, University of Rochester (1976). Taught courses in Applied Mathematics and Geophysical Fluid Dynamics. Research on numerical fluid dynamics and hydrodynamic stability. Development staff member of the Engineering Technology Division of the Oak Ridge National Laboratory (1977-1980). Served as Program Manager of the Meteorological Effects of Thermal Energy Releases (METER) Program addressing the environmental effects of waste heat. Led several field studies around the Bowen Electric Generating Plant in Northwest Georgia concentrating, primarily, on the study of cooling tower induced precipitation modification. Specialized studies dealt with investigations of smokestack plume washout as a means of understanding "acid rain" mechanisms.
Selected Publications	Patrinos, A. A. N. and Kistler, A. L. A numerical study of the Chicago Lake breeze. Boundary-Layer Meteorol. 12, 92-123 (1977). Patrinos, A. A. N., Chen, N. C. J., and Miller, R. L. Spatial correlations of monthly rainfall: Applications in climatology and weather modification experiments. J. Appl. Meteorol. 18, 719-732 (1979). Patrinos, A. A. N. and Bowman, K. O. Weather modification from cooling towers: A test based on the distributional properties of rainfall. J. Appl. Meteorol. 19, 290-297 (1980). Patrinos, A. A. N. and Leach, M. J. On the use of the pseudo-spectral technique in air pollution modeling. For presentation at the Third Joint Conference on Applications of Air Pollution Meteorology, January 11-15, 1982, San Antonio, TX. To appear in preprint volume.

GILBERT S. RAYNOR — Meteorologist

Education	U.S. Navy Aerographer's School, 1942; U.S. Navy Radiosonde School, 1942; Hofstra University (B.S., Applied Physics, 1962).
Research Interests	Atmospheric Diffusion, Micrometeorology, Coastal Meteorology, Precipitation Chemistry, Deposition, Ecology, Ornithology.
Professional Affiliations	American Meteorological Society; American Ornithologists' Union; Wilson Ornithological Society; American Society of Mammalogists.
Summary of Experience	With Division of Atmospheric Sciences (formerly Meteorology Group) since 1952. Associate Head, 1981. Plan and conduct field experiments in coastal meteorology, micrometeorology, diffusion and precipitation chemistry. Recently conducted studies of transport and diffusion climatology of U.S. East coast for site planning and a study of meteorological programs for nuclear reactor sites. Coordinated multi-lab aircraft sampling program for EPA's NEROS program. Planned and directed the interlaboratory MAP3S/RAINE Intermediate Density Precipitation Chemistry Experiment. Formerly planned and directed studies in particle deposition, pollen dispersion and spray droplet behavior in the atmosphere. Designed several new types of particle sampling instruments and sequential precipitation sampler. Author of numerous papers and reports.
Selected Publications	Raynor, G. S., SethuRaman, S., and Brown, R. M. Formation and characteristics of coastal internal boundary layers during onshore flows. Boundary-Layer Meteorol. 16, 487-514 (1979). Raynor, G. S., Michael, P., and SethuRaman, S. Recommendations for meteorological measurement programs and atmospheric diffusion prediction methods for use at coastal nuclear reactor sites. NUREG/CR-0936; BNL-NUREG-51045, October 1979. Raynor, G. S. and Hayes, J. V. Acidity and conductivity of precipitation in central Long Island, New York in relation to meteorological variables. Water, Air and Soil Poll. 15, 229-245 (1981).

S. SETHURAMAN	Meteorologist
Education	Central Polytechnic, Madras, India (Diploma, Civil Engineering, 1958); Institution of Engineers, India (B.E., Civil Engineering, 1966); University of Roorke, India (M.E., (Hons.) Hydraulics, 1969); Colorado State University (Ph.D., Fluid Mechanics, 1972).
Research Interests	Air-sea Interaction, Coastal Meteorology, Atmospheric Turbulence and Diffusion, Air Pollution, Micrometeorology, Planetary Boundary Layer, Tropical Meteorology.
Professional Affiliations	American Meteorological Society; American Geophysical Union; Adjunct Associate Professor, Department of Applied Science, New York University, NY; Adjunct Associate Professor, Marine Sciences Research Center, State University of New York, Stony Brook, NY. Contributing Editor, Lecture Notes in Coastal and Estuarine Studies, Springer-Verlag, NY.
Committees	Member, Committee on Ocean-Atmosphere Interaction of the American Meteorological Society, 1979-1982.
Summary of Experience	Conducted several air-sea interaction studies to understand the variation of wind stress over oceans and to parameterize the surface drag coefficient as a function of sea surface roughness. Studied modifications in the atmospheric boundary layer structure at land-sea interface and coauthored a report to the Nuclear Regulatory Commission recommending meteorological measurements for the siting of nuclear power plants at coastal sites. Participated in the International Monsoon Experiment (MONEX 79) and the 1980 International Solar Eclipse Experiments. Participated in the Indo-American Workshop on Marine Science of 1978 and on the Environmental Protection Agency Workshop on Meteorological Instrumentation, 1980.
Selected Publications	SethuRaman, S., Michael, P., Tuthill, W. A., and McNeil, J. An observation system used to study the marine boundary layer over Bay of Bengal during Summer MONEX 79. Bull. Am. Meteorol. Soc. 61, 1204-11 (1980). SethuRaman, S. A case of persistent breaking of internal gravity waves in the atmospheric surface layer over the ocean. Boundary-Layer Meteorol. 19, 67-80 (1980). SethuRaman, S. and Raynor, G. S. Comparison of mean wind speeds and turbulence at a coastal site and an offshore location. J. Appl. Meteorol. 19, 15-21 (1980).

JOYCE L. TICHLER	Senior Computer Analyst
Education	Barnard College (B.A., Mathematics, 1960); Columbia University (M.A., Mathematics, 1961).
Research Interests	Hardware and Software Systems for Acquisition and Analysis of Experimental Data; Statistical Analysis of Experimental Data.
Professional Affiliations	Association for Computing Machinery; Special Interest Group for Graphics; ACM.
Summary of Experience	Responsible for design and implementation of systems of computer programs used to calibrate, graphically display, form a data base of, do quality control on, statistically analyze and produce data reports for data collected in experimental programs of the Atmospheric Sciences Division. Maintain and disseminate on request a climatological data base of BNL. Provide consultation services on statistical and general computer problems arising in the work of the division. Involved in continuing project for the Nuclear Regulatory Commission (NRC) to maintain a data base of effluents released by operating nuclear power plants and generate annual reports on effluent releases. Currently involved in designing hardware and software for a computer system to perform real time data acquisition aboard the BNL "Islander" aircraft.
Selected Publications	Tichler, J. and Benkovitz, C. M. Radioactive materials released from nuclear power plants. Annual report 1978. BNL-NUREG 51192, NUREG/CR-1497, March 1981. Brown, R. M. and Tichler, J. L. Recommendations for portable supplemental meteorological instrumentation for incident response. BNL-NUREG-51295, NUREG/CR-1954, March 1981. Michael, P., Tichler, J., Hoffert, M. and Tobias, M. Transient climate response to changing carbon dioxide concentration. Climatic Change 3, No. 2, 137-153 (1981).