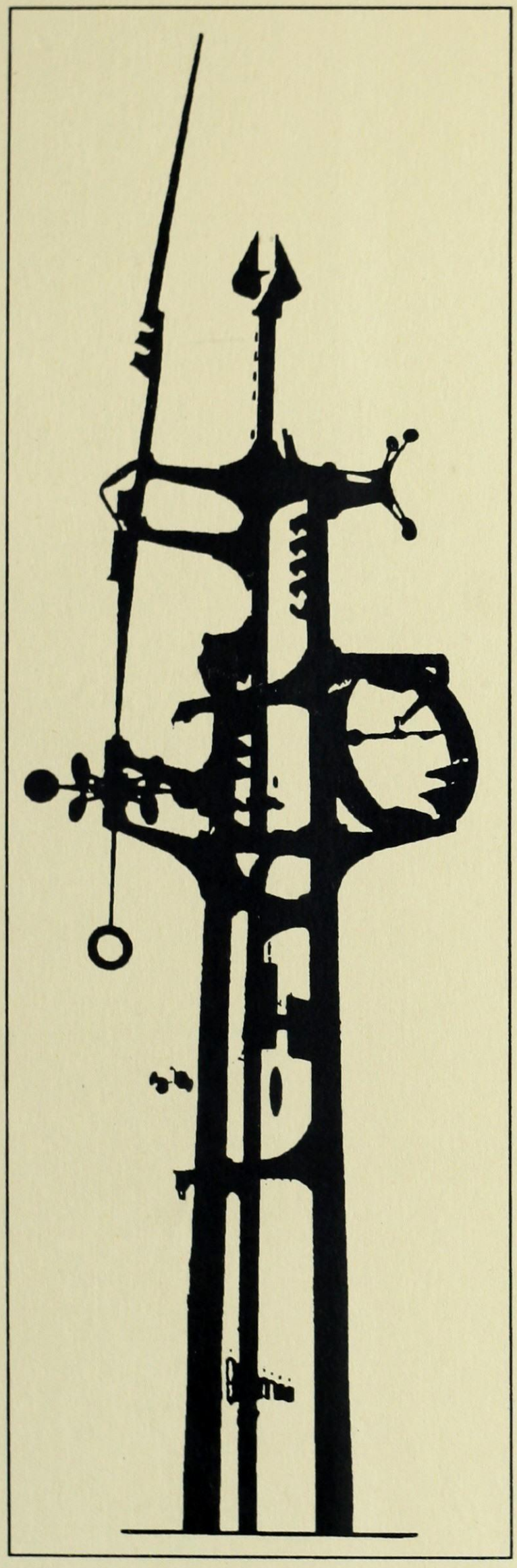

AIR QUALITY

RESEARCH BRANCH

ANNUAL REPORT

1993-94

Environment Canada | Environnement Canada

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AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

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Compiled by

Malcolm E. Still

July 1994

Air Quality Research Branch
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario, Canada M3H 5T4

TABLE OF CONTENTS

AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

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1.0 FOREWORD

1.1 Editorial
- H. Martin

Over the past year the Canadian economy and the fiscal constraints in government have impacted on all of us. The research program in the Air Quality Research Branch has managed its share of resource reductions. Nevertheless, as can be seen in the following report, the Branch has maintained a sterling level of productivity, thanks to the dedication of each member. We have, of course, benefited from the continuing substantial support from the Green Plan and other special funding mechanisms, particularly the Great Lakes Water Quality program. However, resources are not the only fuel that has maintained our productivity and vigour. Dedication, collaboration and cooperation are also powerful ingredients which have led to a very successful program.

The future will have its difficulties but already we see reason for optimism and continued success. Our new laboratories at Downsview will be nearing completion during 1994-95. These facilities will provide much needed quality space for the advancement of the acid rain, air toxics, smog and greenhouse gas programs. In addition, our ongoing and improved collaboration with atmospheric science programs in the U.S. and elsewhere will continue to benefit our initiatives, and will ensure continuing high productivity and the delivery of appropriate scientific information to the government for inclusion in the development of public policy.

Although scientific inquiry seems to have lost some of its prestige in the current agenda, the need to address problems relating to air pollution and their impacts on the natural environment and humans will continue to be a pressing matter for some time to come.

1.2 Awards
- M. Still

Each year the Air Quality Research Branch recognizes AES employees that have contributed significantly to the achievement of the goals of this Branch. This "All Seasons Research Award" was initiated in 1988 and to date there have been 26 winners. A plaque indicating the past winners is on display in the DOE library at 4905 Dufferin Street. The 1993 winners were:

Bill Hart for his effort in establishing the stratospheric ozone observatory at Eureka, N.W.T., which opened one year ahead of schedule with measurements starting in January 1993.

Wes Kobelka for his design and implementation of an exceptional sampling system for controlling the air filter pack and ozone sampler at CAPMoN sites which is recognized internationally for its operation in some of the remotest areas of the world.

David MacTavish for planning and implementing the move of the CAPMoN precipitation analysis laboratory from Burlington and the CAPMoN air analysis laboratory from AES Downsview to a new integrated facility at York University.

Tom McElroy for bringing credibility and public awareness to the efforts of the Branch through his continuing activities in measuring stratospheric ozone from several international platforms, such as the space shuttle and the NASA research aircraft ER-2.

Bruce Thomson for his demonstrated leadership and dedication in the development of regional air quality services through the recruitment, training and development of a talented staff for his regional air quality unit.

Also this year, Dr. Ying Qi, a post-doctoral fellow in the Branch, was awarded the *Changwang Tu Young Meteorologist Prize (Highest Grade)*, presented biannually by the Chinese Meteorological Society.

1.3 Resource Report
- K. Ford and L. Grittani

During this year, the Branch's staff complement increased to 143 persons, including 23 term positions and 6 positions that were filled on a continuing basis.

Research staff participated in 90 conferences throughout the world. This was comprised of 29 in Canada, 40 in the U.S. and 21 in the rest of the world. Staff expertise also contributed to 16 U.S. and 6 international workshops.

The Branch began the 1993/94 fiscal year with a budget totalling $14.5 million of which the largest components were A-Base ($9.3 million) and Green Plan ($4.7 million). Shortly after the year began, funding was confirmed for two other initiatives: $0.8 million from EPS for our Great Lakes Water Quality Agreement program and $0.9 million for our Arctic program in partnership with DIAND.

Other federal government departments and agencies and several cost saving measures contributed approximately another $0.7 million to our budget. Departments, such as External Affairs, Health & Welfare, and Fisheries & Oceans, and federal agencies, like the Canadian Space Agency and the Atomic Energy Control Board, provided funding in support of our research. This clearly demonstrates how highly valued our work is. Many of our programs operate with the involvement of DOE regional offices and other AES Directorates. This has resulted in budget transfers from the Branch exceeding $1.0 million with the major transfers being related to CAPMoN (Acid Deposition), Alert (Climate Change, Toxics) and Eureka (Stratospheric Ozone).

2.0 BRANCH PROGRAM

2.1 ACID DEPOSITION

2.1.1 Lagrangian Model

- M. Olson, K. Oikawa and B. Pabla

The sulphur and nitrogen Lagrangian model code conversions to the NEC SX-3 were successfully completed and tested. Attempts to optimize the trajectory model for NEC operation were only partially successful due to the large amount of input/output data required by the model which prevented significant optimization. The hemispheric wind archive has been updated and the trajectory model was run for several users.

2.1.2 Spectral Data Analysis

- A. Sirois, M. Olson and B. Pabla

A spectral analysis of ADOM (Acid Deposition & Oxidants Model) and measured data for EMEFS (Eulerian Model Evaluation Field Study) showed the existence of a diurnal cycle in ozone concentration at all measurement sites and at all equivalent ADOM grid points, except for points near Chapais and Kejimkujik where model diurnal variation was almost nonexistent. The explanation for this effect seems to be related to the lack of nitrogen emissions in the model inventory at and near these grid points so that little ozone is produced or destroyed on a daily basis.

2.1.3 ADOM Evaluation

- K. Puckett, C. Banic, R. Hoff, S. Li, R. Leaitch, A. MacDonald, R. Mickle, M. Moran and H. Wiebe

Work continued on the analysis of the ADOM performance for the summer EMEFS 1988 period using the absolute principal component analysis technique and comparing the model to the enhanced chemistry data from Egbert. The analysis has revealed certain deficiencies of the model, for example, there is a hint that the nitrogen chemistry occurs too fast.

Work also continued on the evaluation of model performance for the spring 1990 EMEFS period for measurements of O_3, H_2O_2, SO_2 and NO_x aloft. Both level flight segments and vertical profiles over Egbert and Lake Traverse were compared to model predictions. Initial comparisons showed relatively good agreement between the model and the measurements aloft. In particular, the increase in oxidant concentrations during the transition from winter-like to summer-like conditions is well represented in the model.

Results from the latest ADOM run were compared with the upper air ozone flights taken at Egbert during EMEFS II (Spring 1990). The periods when flow was from the north were compared with the upper air flights from Alert during the same period and were found to closely resemble the Alert profiles, except in the boundary layer where the Alert profiles showed a more rapid decline in ozone below 1 km. ADOM was found to continue to underestimate the measured profiles by 10 to 40%. The underestimation occurred at all levels but was most severe in the lower levels for northerly flows and in the upper layers for southerly flow. From measurements, stratospheric injections were found to influence ozone concentrations down to 4 km leading to a severe underestimate of ozone in these levels.

2.1.4 Dry Deposition Modelling

- J. Padro and J. Walmsley

The ADOM concentration estimates of O_3 and SO_2 showed some sensitivity to different

formulations of the dry deposition but these changes were not sufficient to explain the large model underestimates when compared with the observations. Another study comparing the ADOM-RADM dry deposition modules revealed that incorporating the RADM (Regional Acid Deposition Model) aerodynamic resistance formulation for stable conditions in ADOM would yield improved results. ADOM and its modified version were also applied to the California Dry Deposition O_3 Experiment (CODE) data, yielding an increasing number of parameters for modelling dry deposition over a larger number of land-use categories. CODE included a vineyard, and a cotton and grass field.

The effect of dry deposition on some chemical species in the MSFD (Mixed-Spectral Finite-Difference) model concentration output over a gentle hill is being investigated. A modified version of Wesely's (1989) surface resistance parameterization is being employed to formulate the surface boundary condition of concentration over a gentle hill.

2.1.5 ADOM Simulations - Wet Deposition
- J. Brook

The ADOM model has been undergoing intensive evaluation in order to assess its ability to correctly simulate the chemical and physical processes in the troposphere over eastern North America. The purpose of the Aggregation Study is to develop a method for estimating long-term deposition patterns using a small number of ADOM episodic simulations. All of the time periods occurring after 1987 that ADOM has been set-up to run have been examined for possible inclusion in this small number of episodes. Thirty-three three-day episodes have been identified based upon their meteorological characteristics and on their ability to combine to produce good approximations of the long-term pollutant deposition patterns and source-receptor relationships over Canada. The next step will be to supplement the 33 episodes with time periods selected to improve estimates of the long-term ambient sulphate and visibility distributions.

2.1.6 Dry Deposition Estimates
- J. Brook and N. Koshyk

Five different types of resistance-based inferential models for estimating dry deposition are being compared: land-use model (Voldner, Sirois and Barrie); big leaf model (Hicks); multi-layer model (Baldocchi); ADOM model (Padro); and RADM model (Wesely). Each model utilizes different parameterizations to estimate the aerodynamic and surface resistances. The comparison is being conducted to determine which modelling approach produces the most realistic results and under what conditions.

Thus far, three of the models have been compared to the O_3 flux data collected in Borden in 1988 and 1990 (deciduous forest) and in California in 1991 (vineyard). The models captured the observed mean diurnal patterns in O_3 dry deposition velocity in the summer reasonably well. However, both day and night deposition velocities were generally under-predicted by the multi-layer model, while the bias associated with the big leaf and ADOM models varied between the vineyard and the forest, and between day and night. Springtime ozone deposition velocities over the forest (Borden 1990) were significantly under-estimated by the big leaf and multi-layer models. They did not reproduce the observed mean diurnal pattern. The ADOM module deposition velocities did exhibit a diurnal pattern and on average they were closer to the observed rates.

2.1.7 Canadian Acid Aerosol Measurement Program
- J. Brook, H. Wiebe and S. Woodhouse

There are now three complete summers of data (1991, 1992 and 1993) for the Canadian Acid Aerosol Measurement Program (CAAMP) for Sutton, Windsor and Egbert. In accordance with the original study design, which planned for short surveys at a variety of locations, sampling was discontinued at Sutton (September 1993) and at Windsor (April 1994). These sites were replaced by Halifax (February 1994) and Hamilton (April 1994). As reported previously, particulate levels in the summer of 1992 were found to be quite low. This trend continued in the summer of 1993, with all sites reporting even lower levels. This is surprising since compared (qualitatively) to 1992 there was less rain and cool weather in 1993. The meteorological or chemical reasons for the low levels in both of these years have yet to be investigated.

The data available through 1993 indicate that fine particle acidity is highest at the Saint John site. A 24-hour sample collected August 3-4, 1993, had an acidity of 229 $nmoles.m^{-3}$ and a SO concentration of 127 $nmoles.m^{-3}$. A molar ratio of almost 2.0, which corresponds to unneutralized sulphuric acid! The SO and H^+ data from Saint John and Kejimkujik were compared and the results suggest that at least 33 % of the sulphate and associated acidity at the Saint John site is emitted locally. These results and Health Canada's interest in

studying the health effects of atmospheric particulate matter have led to plans for more intensive monitoring in Saint John in 1994.

2.1.8 Biogenic Sulphur in Coastal Regions
- S.-M. Li

At three CAPMoN sites (Saturna Island, ELA and Kejimkujik), biogenic contributions to total aerosol sulphate are now being evaluated by using methanesulfonate ion (MSA) as the tracer species. MSA has been determined in the aerosol samples during April 92 - June 94. It shows distinct seasonal variation patterns at all three sites.

2.1.9 Visibility Research
- R. Hoff, L. Guise-Bagley, K. Puckett and K. Macdonald (WAESD)

The Canada-U.S. Accord on Air Quality recognizes that preventing significant air quality deterioration and protecting visibility is important to both countries. It requires the United States to apply the U.S. Clean Air Act to sources that could cause significant transboundary air pollution and requires Canada, by January 1, 1995, to develop and implement means of affording levels of prevention of significant air quality deterioration and protection of visibility comparable to the U.S. legislation.

A technique has been developed to extend airport visibility data past the range where reporting procedures censor the data. This involves fitting a Weibull distribution to data at ranges where the data is believed to be correctly observed (1-14 miles) and extending that distribution to the median frequency (50%). This median visibility estimate is believed to be more robust than the median of the raw data which has many 15+ miles coded into the climate data base. This data set was expanded to include 140 hourly climate stations in Canada, and maps of the visibility by season and year have been drawn to give a historical record of median visibility in Canada since 1951. This will be the baseline to determine changes in visibility in the future.

Techniques have been tested by which visibility reduction can be apportioned to the aerosol types which scatter and absorb light. During the 1992 Egbert Aerosol Study, particle size measurements in the range 20 nm to 20 mm were measured, coincident with light scattering measurements using an ambient nephelometer, a transmissometer and a lidar. The results are being used to determine the amount of particle growth from humidity, aerosol scattering and absorption properties, and a radiation balance for the scattering process. Preliminary results show that photochemistry in Ontario may be producing a large number of particles in relatively clean air in the middle of the morning and that these particles are effective light scatterers.

In addition to the above studies, sampling of visibility-reducing aerosols was initiated in an area of concern to the U.S. - the Glacier/Waterton Lakes International Park. In cooperation with the U.S. National Parks Service, two sites are now operating in these parks (one on the Canadian side at Waterton, Alberta, and one on the U.S. side in Glacier National Park). This research effort involving Environment Canada regional staff in Edmonton will analyze reduced visibility with air transport from sources in Washington, Idaho, Montana, British Columbia and Alberta.

In British Columbia, a significant effort to understand visibility reduction in the Lower Fraser Valley is underway. The Pacific '93 field experiment, which was designed to look at oxidant related issues in the valley, has been expanded to study aerosol movement in this region. This involves the use of airborne lidar, particle sizing probes and nephelometry. In addition, the Province of British Columbia, in cooperation with the regional offices of Environment Canada and the University of British Columbia, is analyzing data from ten IMPROVE sampling stations, three nephelometers, a transmissometer and an extinctiometer. While the intensive phase of this program lasted only for the summer of 1993, an on-going program of monitoring involving in-situ and optical sampling is being carried on.

2.1.10 CAPMoN Operations
- W. Kobelka, A. Gaudenzi, M. Underwood, S. Iqbal and R. Vet

The Canadian Air and Precipitation Monitoring Network (CAPMoN) consists of 23 precipitation chemistry sites, 11 air chemistry (filter pack) sites and 7 ozone monitoring sites. The operations were coordinated in Downsview and managed by DOE Regional Inspection staff. Several network changes took place during the year. The termination of sampling at the Cree Lake site on May 5, 1993, resulted from the closure of the Cree Lake upper air station. A new precipitation site, located at Long Pointe du Mingan in Quebec, opened on November 29, 1993, as a replacement for the closed site at Port Cartier, Quebec. The Harcourt, New Brunswick, precipitation site was relocated approximately 1 km away due to the retirement of the site operator. A 4-month

comparison study between the old and new sites at Harcourt showed excellent comparability during periods of frontal precipitation and moderate to good comparability during convective periods.

Development work was completed on a new generation precipitation chemistry collector. The new collector, known as the MIC Model C300, was operated in parallel with the old collector at the Centre for Atmospheric Research Experiments in Egbert, Ontario. The comparability of the two instruments was well within 10% and no operational problems were detected. Some of the features of the new collector are a redesigned circuit board, more reliable switching technology and improved bucket coverage by the roof. Approximately half the network collectors have been converted to the C300 specifications.

Improvements were made to the CAPMoN filter pack sampling head to increase its serviceability and safety. The improvements included a latching system which allows easy access to the inside of the equipment, a redesigned circuit board, and the isolation of the signal cable from the power cable.

CAPMoN staff were actively involved in providing advice and assistance to scientists from the Peoples Republic of China as they implemented a new Global Atmospheric Watch site on Waliguan Mountain in central China. This is a continuing project carried out under the auspices of the World Meteorological Organization.

2.1.11 CAPMoN National Laboratory

- D. MacTavish, R. Braga, R. Kessler, N. Lance and K. So

All laboratory analyses, and subsequent data sets related to CAPMoN's 1993 monitoring programs, were completed by February 1994, for precipitation samples and by March 1994, for air filters. This includes the analysis of 15,000 filters and 7,000 precipitation samples that involved more than 140,000 chemical determinations. In addition, the analyses of CAPMoN and dichotomous filters sampled during 1993 at Esther, Alberta, in support of a program designed to provide information on the suitability of using open-face filter packs in a dusty environment were finalized.

The laboratory continued to participate with success in all international laboratory intercomparison studies. These include the Environment Canada Long-Range Transport of Air Pollutants Intercomparison, the World Meteorological Organization - Global Atmospheric Watch Laboratory Intercomparison, the United States Geological Survey Intercomparison, and the European Measurement and Evaluation Program Laboratory Round Robin Study.

Advances in automation, combined with increased efficiency and a more experienced team of analysts, has allowed the laboratory to decrease its personnel by two to a total of five. The laboratory has added Ca^{++} and Mg^{++} to those analytes already being determined from Teflon filters. This additional information will be available upon the completion of the 1994 data set.

2.1.12 CAPMoN Quality Assurance & Data Management

- R. Vet, M. Shaw, S. Iqbal and S. Ahmed

The CAPMoN air, precipitation and ozone data underwent quality control/quality assurance and were finalized up to December 31, 1992. As scheduled, data from April to September 1993 were quality controlled by March 31, 1994. A new computer-based system was implemented for blank-correcting the filter chemistry data, resulting in a significant improvement in data turn-around time. Work continued on the CAPMoN Analysis and Statistical Reporting (CAPSTAR) software package to be used for distributing CAPMoN precipitation chemistry data. Completion is expected in May 1994. An audit/inspection/calibration system was developed for the ozone quality assurance program, and testing was undertaken on 3 ozone calibration instruments for use in the system. CAPMoN staff responded to 55 requests for data and analyses by various government, scientific and private sector agencies.

2.1.13 NAtChem Data Base

- R. Vet, C. Ro, B. Sukloff and D. Ord

The National Atmospheric Chemistry Data Base (NAtChem) focused on several initiatives: updating the precipitation chemistry data base to 1991; preparing input for the 1994 Progress Report of the Canada-U.S. Air Quality Accord; undertaking prepublication work on the NAtChem 1990 and 1991 Annual Reports, and on the NAtChem NADP/NTN 1980-1991 Annual Report; and preparing the report "Spatial Patterns of Acid Precipitation in Eastern North America from 1980-1991" to be published soon. The NAtChem data base was updated to 1991, including the complete U.S. NADP/NTN and CASTNET (the Clean Air Status and Trends NETwork) data sets.

In collaboration with the Quebec Ministry of the Environment, NAtChem staff undertook a network optimization study which involved investigating which sites could be eliminate from the Réseau

d'échantillonnage des précipitations du Québec. NAtChem staff also responded to 63 other data and analysis requests. NAtChem personnel directed the development of a PC-based mapping and interpolation software package. This package was designed to replace the old mapping/ interpolation software scheduled to disappear with the AES mainframe computer in June 1994.

2.1.14 Adequacy of Sulphur Emission Controls

- D.M. Whelpdale and A. Sirois, in cooperation with C.B. Blanchard and S. Dorling

The objective has been to develop and apply techniques to assess the suitability of monitoring networks in eastern Canada to detect changes in wet sulphate deposition ($D_w(SO_4)$) that are expected as a result of emission controls in Canada and North America between 1980 and 2010.

A set of statistical techniques has been developed and applied according to two performance criteria: the ability of CAPMoN to detect and quantify projected regional trends in precipitation sulphate concentration in a timely fashion; and the ability of CAPMoN to delineate both past and projected future spatial patterns of $D_w(SO_4)$.

In the area of southern Canada now receiving in excess of 20 kg/ha/y $D_w(SO_4)$, the seven CAPMoN stations would be able to detect and quantify projected regional trends nearly as soon as the 41 stations now operating in the area. However, in regions now receiving less than 20 kg/ha/y $D_w(SO_4)$, CAPMoN would require four to eight years longer than the larger set of currently available stations to detect projected reductions. The current configuration of CAPMoN is adequate to monitor some areas with sulphate deposition exceeding 20 kg/ha/y until deposition goes below this value, but not those areas situated in extreme southwestern and southeastern Ontario, southern Quebec, and the Bay of Fundy region. In comparison to using all currently operating monitoring stations, using only CAPMoN stations underestimates the area in which $D_w(SO_4)$ exceeds 20 kg/ha/y.

The techniques have also been extended to permit evaluation of the need for specific individual sites, comparison of more configurations of the network, and consideration of more regions. Parameter estimates for the statistical model have been improved by using monthly instead of annual data. For the regions that were examined, eliminating all provincial sites in Eastern Canada would cause an increase of one to six years in the time required for reaching a 90% probability of detecting the expected future trends. The elimination of certain key provincial sites may generate uncertainties in the determination of deposition isopleths of particular interest, such as the 20 kg/ha/y contour.

The techniques developed are quite general and can easily be extended to statistical tests or estimators other than those used in this study.

2.1.15 Global Acid Rain Assessment

- D.M. Whelpdale and P.W. Summers, in cooperation with R.S. Artz, G. Ayers, H. Dovland, J.N. Galloway and J.M. Miller

The project objective is to conduct a global assessment of the status of the acid deposition phenomenon. The project is sponsored by United Nations Environment Program and administered by the World Meteorological Organization. Experts from various regions of the world have completed the tasks of gathering and evaluating available data on the wet and dry deposition of sulphur, nitrogen and related species.

Draft chapters for nine regions of the world (Europe, North America, the Middle East, the Former Soviet Union, East Asia and Oceania, South and Central America, Africa, Polar Regions and Marine Regions) have been completed which summarize available information on the magnitude, spatial distribution and temporal trends in acid deposition. A context for these regional assessments is provided by additional chapters on processes and effects of acid deposition.

Major findings include evidence of reductions of acid deposition in the three areas of the world where acid rain has been a problem over the past decade and more -- eastern North America, western Europe and Japan. On the other hand, there is evidence of an substantial acid deposition problem developing in southeast Asia as a result of the intense development occurring in that part of the world. Evaluation of available data shows that BAPMoN (Background Air Pollution Monitoring Network) has suffered from inadequate quality assurance over the years, with the result that much of the data from this network are unreliable.

The assessment concludes that the acid deposition problem is far from being solved in some areas of the world, that measurement coverage is completely inadequate in much of Asia, Africa and South America, and that substantially more effort must be devoted to ensuring data quality in monitoring programs. A final report of this project is now in preparation for submission to UNEP and subsequent publication.

2.2 NOx/VOC MANAGEMENT PLAN

2.2.1 Program Management

- M. Lusis and R. Vet

The major activity was the planning for Pacific '93: the field study that was carried out in July and August 1993. Another notable milestone was the completion and reporting of an analysis of ground-level ozone data gathered throughout Canada during 1980 to 1991.

Work continued on the development of models for the Lower Fraser Valley, Windsor-Quebec Corridor and Southern Atlantic Region; on the monitoring of ozone (and, at some stations, ozone precursors); and on the investigation of the effects of ozone on human health and vegetation.

As a result of the peer review of the NOx/VOC (Nitrogen oxides and volatile organic compounds) Science Program in March 1993, a number of changes were instituted both in program management and in the level of resourcing to different program components. A Scientific Coordination and Assessment Committee was formed for overall coordination of the Science Program, and this Committee developed a detailed Program Plan. Efforts were also intensified to garner resources from other stakeholders, especially the industrial sector.

2.2.2 Pacific '93

- J. Bottenheim, M. Lusis, K. Anlauf, S. Li, A. MacDonald, H. Wiebe, M. Watt, A. Tham and A. Gaudenzi

The Pacific '93 field study - the largest experiment of its type conducted to date in Canada - took place in the Lower Fraser Valley during the period July 15 - August 12, 1993, under the Canadian Institute for Research in Atmospheric Chemistry (CIRAC) umbrella. It was coordinated by AES and the University of British Columbia, and included contributions from the Greater Vancouver Regional District, the British Columbia Ministry of Environment, Lands and Parks, and the academic, industrial and consulting sectors. The study was to improve our understanding of the atmospheric processes that lead to oxidant formation in the Lower Fraser Valley, and to provide data for the development of models which will be used for emissions control strategy development.

The existing network in the area was greatly enhanced with additional air quality and meteorological measurements, including sampling from an instrumented aircraft. The measurements emphasized not only the initial reactants (NOx and VOC) and ozone, but also reaction intermediates and other important smog products (peroxyacetyl nitrate (PAN), hydrogen peroxide, organic nitrates and free radicals). The aircraft equipment included a downward-looking lidar which was used to map the development and movement of haze layers in the study area.

During the study, a comprehensive data set was collected on ozone, other smog products, and reaction precursors and intermediates, as well as concurrent meteorological data, which will be used for model evaluation and development. A workshop was held in Vancouver in April 1994, where the data were presented for initial evaluation, scientific publications were planned, and model development applications were considered.

Over 60 hours were flown with the Convair 580 over the Lower Fraser Valley at altitudes of 60 - 4,200 m measuring ozone, nitrogen oxides, PAN and filterable particles. Ozone, NO and NO_y data have been quality assured and the data set is in final format. One particularly smoggy episode during the first week of August was carefully characterized.

As well, air samples were collected with a mist chamber system (scrubbing technique of passing air through a fine water mist) and analyzed by ion chromatography. Throughout the study, approximately 150 samples were collected on 15 flights. Sample resolution ranged from 30 minutes at high altitudes to less than 10 minutes within the boundary layer. Field analyses showed that formic and acetic acid measurements were below the detection limit of the mist chamber. These samples were successfully analyzed on site for HNO_3 and a good geographic coverage of HNO_3 can be obtained for the valley.

A surface site near the Pitt River was set up to measure surface meteorology, ozone, nitrogen oxides, sulphur dioxide, filterable particles, nitric acid, ammonia, formaldehyde and hydrogen peroxide. Continuous sampling for HNO_3, HNO_2 and corresponding particle species were also carried out using the denuder-filter pack sampling system. Most of the samples for HNO_3 and HNO_2 were analyzed using an ion chromatograph on site with a high success rate, while the particle samples were analyzed at the AES laboratory at Downsview. In addition to the denuder-filter pack sampling system, a system of continuous and real-time measurements of HNO_3 was deployed toward

the latter part of the field study and was proven to be highly successful. Denuder data and continuous HNO_3 data have been quality controlled.

2.2.3 CAPMoN Ozone Measurements

- W. Kobelka, A. Gaudenzi, M. Underwood, S. Iqbal and R. Vet

Continuous ozone sampling took place at seven of the 11 CAPMoN air and precipitation monitoring sites. The measurements were made under the auspices of the Green Plan NOx/VOC Science Program and the resultant data will be placed in the National Air Pollution Surveillance (NAPS) Data Base. The raw data collected at 6 of the 7 sites were telemetered to AES, Downsview, where they were subjected to quality control and evaluation. An audit/inspection/calibration system has been designed for implementation in the coming year. Three ozone calibrators were purchased and tested for use in this system. A comprehensive Air/Ozone Measurements Manual is being prepared that will cover all aspects of the measurement system from installation to calibration.

2.2.4 BOREAS Tower Flux Measurements

- H. Neumann, G. den Hartog and R. Staebler

This study is but one component of an international study, BOREAS (Boreal Ecosystem-Atmosphere Study), which is jointly sponsored by NASA in the United States and by several federal agencies in Canada.

The objectives of BOREAS are: (i) to improve our understanding of the processes and states which govern the exchanges of energy, water, heat, carbon and trace gases between boreal forest ecosystems and the atmosphere, with particular reference to those processes and states that may be sensitive to global change; and (ii) to develop and validate remote sensing algorithms to transfer our understanding of the above processes from local scales out to regional scales.

The objectives of this study are to quantify and examine the controlling factors for CO_2, O_3, CH_4 and N_2O exchange at the Old Aspen site in Prince Albert National Park, Saskatchewan, and to determine diurnal and seasonal surface energy fluxes at this site.

Four categories of measurements are proposed: (i) eddy correlation flux measurements of momentum, sensible heat, latent heat, CO_2, O_3, CH_4 and N_2O above the canopy; (ii) within and above canopy profiles of temperature, H_2O and CO_2; (iii) half-hour means of wind speed, wind direction, incoming solar radiation, net radiation, PAR, temperature, relative humidity, wet precipitation, O_3 above the canopy, IR canopy temperature, and soil heat flux and temperature; and (iv) tethersonde profiles including O_3. These measurements have been identified as essential in the BOREAS Science Plan.

Our field studies were initiated in a pre-experiment conducted at our site at the Borden Forest. This was a month-long campaign that served as a shake-down for the methods and instrumentation and it marked the first tests of making eddy correlation measurements of methane and nitrous oxide fluxes above a deciduous forest with tunable diode lasers. The first measurements at the Old Aspen Site were conducted from October to November 1993. This campaign followed the slow decline in carbon dioxide and other fluxes over the aspen forest as the season progressed from autumn to early winter. Further studies an the Old Aspen site were conducted during the midwinter (February 1994) giving a measure of the small fluxes in the most dormant phase of the forest's annual cycle, as well as providing support to snow hydrology studies going on concurrently. Measurements initiated for the winter study will continue until the culmination of the 1994 BOREAS field season in September 1994.

2.2.5 Nighttime NO_y Chemistry

- H. Wiebe, K. Anlauf, R. Hoff, R. Mickle, S. Li, M. Watt, A. Gaudenzi and A. Tham

During the week of August 22-29, 1992, measurements of the precursors leading to nighttime formation of particle nitrate were made at Egbert, Ontario. The chemical species measured included O_3, NO, NO_2, N_2O_5, HNO_3, NH_3 and particulate nitrate. Particle size distributions were also measured and indicate that there is a growth to larger-sized particles during the night as particulate nitrate forms. Profiles of meteorological parameters and of O_3 and NO_2 concentrations were measured within the nocturnal layer using a tethersonde with an attached sampling manifold. The general features include complete titration of NO by ozone, elevated levels of NO_2 and decreased concentrations of O_3 within the nocturnal layer. The data set has been finalized and will be compared to an existing chemical reaction scheme for the formation of particle nitrate from N_2O_5. The results of this analysis should result in the modifications to the current gas phase chemistry module in both the ADOM (Acid Deposition & Oxidant Model) and the ALOM (AES Lagrangian Oxidant Model).

2.2.6 Hydrocarbon Emissions

- G. den Hartog, J. Fuentes, H. Neumann and J. Deary

Field experiments were carried out during 1993 to measure the hydrocarbon emissions from individual branches of several tree species, and the ambient hydrocarbon concentrations and detailed microclimatic conditions within and above the deciduous Borden forest canopy. In addition, micrometeorological hydrocarbon fluxes above the forest canopy were measured during two days in September in collaboration with the University of Guelph. Special emphasis was given to the measurements of isoprene, for it was found to be most abundant phytogenic hydrocarbon species in the ambient air. Analyses of samples gathered from branch chamber systems and ambient air were performed at the experimental site.

Prior and during outbreak of leaf buds (late April), ambient isoprene concentrations were barely above instrument detection limit (~50 ppt). Isoprene concentrations increased considerably with growing season, reaching maximum concentrations around 500 ppt by the middle of June. Isoprene concentrations varied considerably with time of day and with height with peak concentrations occurring during mid-afternoon. Maximum isoprene concentrations were found within the crown of the canopy, and concentrations declined appreciably with height. Hydrocarbon emissions from red maple, large-tooth aspen, trembling aspen and white ash were measured using a combination of chamber systems and gas chromatography. Red maple and white ash leaves did not release isoprene. During the spring, large-tooth aspen leaves released only moderate amounts of isoprene. Trembling aspen emitted considerable amounts of isoprene (approximately 30 times more than large-tooth aspen). In late August and early September, both trembling and large-tooth aspen leaves released comparable amounts of isoprene, but with considerably higher (5 times more) emissions than the ones measured during spring. This finding suggests that isoprene emissions by the leaves of the studied trees are significantly influenced by leaf ontogeny. Ambient isoprene concentrations during August reached peak values of 8 ppb.

Forest microclimate and photosynthetically active radiation data, covering nearly the entire growing season for the Borden forest, have been gathered to further examine the canopy model used to derive biogenic hydrocarbon emission inventories. Another data set, which includes fluxes for various entities (CO_2, H_2O and O_3) and detailed profiles for several gases (CO_2, H_2O, O_3, NO and NO_2) and air temperature, was obtained as part of the pre-BOREAS experiments carried out at Borden during August 1993. Integrated hydrocarbon emissions at the foliage level and fluxes at the canopy level are being examined to verify whether these two independent methods yield similar results.

2.2.7 Optical Measurements of the Troposphere

- R. Hoff, J. Hahn, A. Sheppard and M. Harwood

The main effort has been the development, installation and first use of an airborne downward-looking tropospheric aerosol lidar system on the NRCC Convair 580 aircraft. This instrument was installed in June 1993 and flown for the first time during the Pacific '93 study. It proved to be a very successful tool for the mapping of aerosol plumes and the general boundary layer of the Vancouver basin. Programs have been written which present the vertical slices of lidar backscattering in the Lower Fraser Valley as a function of latitude or longitude. Also developed are two dimensional contours of integrated lidar backscatter which should be proportional to integrated aerosol mass and thus provide wide spatial details about the distribution of aerosols in the Fraser Valley.

A second development, also used for the first time in Pacific '93, is the differential optical absorption spectrometer (DOAS). This instrument is a long-path light absorption spectrometer using a high intensity lamp, retroreflector array and diode array spectrometer for the determination of a number of trace gas species which absorb in the visible and near ultraviolet. During Pacific '93, attempts were made to measure nitrous acid (HONO), NO_2, and NO_3. To date, only measurements of NO_2 were found to be above the minimum detectable concentrations of the instrument (1 ppb of NO_2, 100 ppt HONO and 70 ppt NO_3). A 1300 m return path was used for the measurements in British Columbia and new processing algorithms are expected to make those sensitivity limits lower.

2.2.8 CHEF Ozone Measurements

- K. Anlauf, R. Schemenauer, K. Hayden and J. Young

Ozone measurements from Roundtop Valley, Roundtop Ridge and Mt. Tremblant have been processed to December 1992. Measurements at the Sutton Valley location were terminated March 31, 1994. A data acquisition system (via modem telephone link) has been installed to enable more efficient access to the CHEF ozone data.

2.2.9 NOx/VOC Modelling
- M. Olson, K. Oikawa and B. Pabla

A contract was let through CIRAC (Canadian Institute for Research in Atmospheric Chemistry) to conduct the model evaluation project for the oxidant models participating in the Windsor-Quebec Corridor/Southern Atlantic Region (WQC/SAR) modelling project. These models are: the ROM 2.2 over the NE North America domain (excluding the Maritimes at present) run by Ontario Hydro; the GESIMA/ADOM over Southern Ontario run by MOEE; the ALOM (Lagrangian Oxidant Model with ADOM chemistry) over the WQC/SAR domain run by AES; and the new modelling system MC2/ADOM run by Janusz Pudykiewicz in Montreal. The first test period (August 1-6, 1988) was selected and the relevant data have been collected into a database. A preliminary set of model evaluation performance criteria have been selected and applied to this base case. Additional measures are being developed.

2.2.10 Southern Atlantic Region Oxidant Modelling
- W. Gong

A numerical study has been initiated: 1) to define the characteristics of the mesoscale flow and marine/coastal boundary layer in order to assess their impact on the oxidants in the Canadian Southern Atlantic Region; and 2) to investigate the role of transport (over water, in particular) and the relative importance of local sources and photochemistry in the region.

MC2 (Meteorological Community model developed by Université du Québec á Montréal and AES in Montreal) is selected as a primary tool in the dynamic study and will be the meteorological driver for the study of transport and transformation of oxidants. To study the land/sea breeze circulation, MC2 is to be run on an approximately 500 km x 500 km domain (43-47°N, 62-68°W) with a grid size of 5 km, and with initial and nesting boundary conditions provided from archives. Version 3 of MC2 was delivered in February 1994. The Southern Atlantic Region runs are in the final data preparation stage.

A transport and a chemistry module are being integrated into the MC2 framework for the transport and transformation study. The transport of reactive and non-reactive scalars are treated in the same manner as the moisture in the MC2 with different external forcing (chemical reaction and other sources/sinks). Surface emission and dry deposition define the lower boundary conditions. The transport component has been completed and preliminary tests were carried out with the earlier version of MC2 (version 2). The development of the interface for the chemistry module is underway.

2.2.11 NATO/CCMS Pilot Study
- J.L. Walmsley

The NATO/CCMS Pilot Study on "Air Pollution Transport and Diffusion over Coastal Urban Areas" sponsored an International Workshop in Athens, Greece, May 1993. Plans were developed for the design of a field experiment to support modelling studies. These will be presented in a report in *Atmospheric Environment*. A final meeting of the Organizing Committee was held in Valencia, Spain, December 1993.

2.3 AIR TOXICS

2.3.1 Program Management
- A. McMillan

The AES Air Toxics Program is made up of the following three major components, each funded separately, the Great Lakes Program, the Arctic Environmental Strategy and the "Keeping Toxics out of the Environment" Green Plan initiative.

The Great Lakes Program under GLAP1 (Great Lakes Action Plan 1) was the fifth year of a five-year program. Hence a significant amount of activity was associated with the planning of GLAP2, known as Great Lakes 2000. The implementation of the Integrated Atmospheric Deposition Network (IADN) continued. A Binational Workshop was held in Toronto in November 1993 at which the committee structure, specified under the Quality Assurance Program Plan (QAPP), was implemented for the first time. The QAPP should be approved at the next Binational Executive Meeting and represents a significant step towards having a network that is effectively "integrated" binationally.

The Arctic Environmental Strategy was led by DIAND. The AES program has major components dealing with the monitoring of organochlorines in the Arctic, the development of global emissions inventories of organochlorines and the linkage of the emissions to the measurements through modelling. AES scientists had significant international influence on the plans for development of ECE protocols on heavy metals and persistent organic pollutants.

Under the "Keeping Toxics out of the Environment" program, AES scientists reviewed a

number of PSL (Priority Substances List) Assessment Documents. Various aspects of the CEPA (Canadian Environmental Protection Act) review were discussed and commented on. Input to a discussion paper for the National Air Issues Coordinating Committee was prepared and a proposal for future work on Hazardous Air Pollutants was submitted to the Air Issues Branch for their consideration.

2.3.2 IADN Master Station Operations

- R. Hoff, F. Froude, P. Heck, F. Maclean, J. Woods and J. Martin

Now nearing its fifth year of operation the Master Station at Point Petre continues to be a focal point for research into air toxics in the Great Lakes. The site is used continuously by AES, NWRI, OME, IWD, and the Illinois State Water Survey.

The results of the master station operations at Point Petre and Burnt Island, as well as the additions research sampling at Egbert, have recently been audited as part of the IADN QA/QC program. A major rewrite of the sampling protocol manual was completed. The data from 1988 to 1991 for metals and for 1990 for the organochlorines is currently being published as part of the IADN cooperation with the U.S.

2.3.3 Organics Analysis Laboratory

- K. Brice, N. Alexandrou, K. Su, L. Liao and M. Shoeib

The Organics Analysis Laboratory (OAL) provides an in-house service for the determination of trace organic chemicals in air samples. This work has focussed towards meeting AES responsibilities within the binational Integrated Atmospheric Deposition Network (IADN). The target species selected for "semi-routine" determination within IADN include polychlorinated biphenyl (PCB) congeners, organochlorine (OC) pesticides and polycyclic aromatic hydrocarbons (PAHs).

Analysis of ambient samples has continued steadily, accompanied by further refinements to the analytical procedures. Considerable efforts were made on the data review which focussed upon the available data deriving from samples collected at Point Petre: a) throughout 1990; b) from the coordinated (AES/OME/ISWS) 1-day sampling periods conducted during 1991; and c) from the coordinated (AES/OME) 4-day sampling periods conducted during 1992. For PCBs/OCs, some adjustments have been required following recent findings of some discrepancies in the reference PCB standard assignments and the results of the IADN Interlaboratory Study (Phase I). For PAHs, major corrections have been required for much of the data in question to incorporate revised multi-level calibration curve information. The concentrations historically assigned to the standards used for instrument calibration prior to August 1992 had been found to be in error due to changes that had occurred to the stocks and substock mixtures during storage.

The development and application of the Research Data Management and Quality Control System (RDMQ) to AES IADN data involved the definition of appropriate approaches for incorporating existing and future laboratory data, the identification of key data quality information for inclusion, the formulation of suitable data output techniques for RDMQ to assist with initial screening, and the development of final data correction procedures and output formats for reporting needs. Within the laboratory, it has been necessary to make major modifications to the methods used for organizing processed data in order to facilitate a flexible approach for data transfer into RDMQ. Improvements have been introduced to allow the introduction of processed data reports into the spreadsheet without the need for manual transcription of data, substantially minimizing errors.

In the IADN Interlaboratory Study Project, the laboratory received batches of solution-phase standards from the Quality Management Office (QMO) at Ontario Ministry of Environment and Energy for determination of a target list of trace elements, PCBs, OCs and PAHs using our normal analytical procedures.

2.3.4 GLWQ Quality Assurance

- S. Cussion

The Integrated Atmospheric Deposition Network (IADN) Quality Assurance Program Plan (QAPP), as originally prepared by a consultant in 1992, was revised and updated. The final revisions were reviewed by all the Canadian and American agencies involved in the IADN program. The document is ready to be approved by the Canadian and U.S representatives to the IJC (International Joint Commission). Two other quality assurance documents also prepared were revised and updated: the Quality Assurance Program Plan (QAPP) for the Air Toxics Program and the Quality Assurance Project Plan (QAPjP) for the Semi-Routine Monitoring Program.

In support of the IADN program, internal audits were conducted of the major components of the

Environment Canada agencies participating in IADN. Audit reports were summarized for the Pt. Petre, Burnt Island and CARE field sampling stations for any areas of concern, mainly gaps in documentation of the Standard Operating Procedures (SOPs). The laboratories audited were the AES Organics Analysis Laboratory, the Organics Precipitation Laboratory at NWRI, the Organics and Trace Metals Laboratories of the National Laboratory for Environmental Testing at CCIW, and the Trace Metals procedure at the Environmental Protection Laboratory. As a result of these audits, assistance was provided in helping revise the Field Manual for the AES Semi-Routine Monitoring Project, the AES laboratory SOPs for OC/PCB and PAH analyses, and the NWRI field and laboratory SOPs.

Four interlaboratory studies were conducted in 1993 together with the Ontario Ministry of Environment and Energy (MOEE). Parameter groups targeted were Trace Metals (Study 93-1, July 1993), Organochlorine Pesticides (Study 93-2, July 1993), Polychlorinated Biphenyls Isomers (Study 93-3, August 1993), and Polycyclic Aromatic Hydrocarbons (Study 93-4, September 1993). Reports have been written on the results.

2.3.5 Atmospheric Mercury

- W. Schroeder and A. Tham

Based on daily atmospheric mercury measurements conducted at Egbert, Ontario, and at Pt. Petre, Ontario, in 1990, the atmospheric input of mercury to Lake Ontario has been estimated. The calculation was performed in 2 ways: a) by considering the deposition (wet and dry) to the lake surface only (315 kg/year); and b) by considering the deposition to the drainage basin of this lake (1060 kg/year). Assuming that 25% of the mercury deposited to the Lake Ontario drainage basin eventually enters the lake, the annual contribution from this source amounts to 265 kg. The vapour exchange flux of elemental mercury between the atmosphere and the lake surface was also calculated at about 95 kg/year.

AES coordinated an atmospheric mercury measurement (sampling and analysis) methods intercomparison in Windsor, Ontario. Scientists from four laboratories participated in this field study: Ontario Ministry of the Environment and Energy (OMEE), Ontario Hydro, University of Michigan, and GKSS Research Centre (Germany). Manual methods of sampling and analysis (U. of Michigan & GKSS) were run side-by-side with two Tekran mercury vapour analyzers (operated by OMEE and Ontario Hydro). Short-term sampling (2 and 3 hour intervals) as well as longer-term sampling (6 to 16 hour intervals) was employed for the manual methods, while the Tekran analyzers were operated with 5-minute sample integration times. The data generated from this study are currently being analyzed.

2.3.6 Air-Water Exchange Processes

- W. Schroeder

The long-term scientific objective is to determine the magnitude and direction of mass transfer (gas fluxes) of volatile and semi-volatile organic chemicals across the air-water interface under conditions representative of the Great Lakes Basin. Phase I, consisting of the design, fabrication, laboratory- and field-testing of prototype versions of an in-situ sparger device and a flux monitor, has been successfully completed.

Improvements to the prototype devices were made during the summer of 1993, and laboratory-based testing of the improved versions of the two devices was then performed both at Concord Environmental Corp. and at the University of Toronto (in a large water tank). Concurrent field trials in Lake Ontario of the second generation of these two devices were carried out during November 1993. During these field trials, both pieces of equipment were observed to be much more stable in the water than their prototypes.

2.3.7 Mercury Measurements at Alert

- W. Schroeder and M. Shoeib

Collection of samples for determinations of atmospheric mercury at Alert, N.W.T., was terminated in August 1993, completing a one-year exploratory measurement campaign. The project involved collection of weekly-integrated samples for total gaseous mercury (TGM) and monthly-integrated samples for particulate-phase mercury determinations in ambient air. All TGM samples have been analyzed. Particulate-phase mercury samples are being stored in a freezer, pending validation of an analytical method.

2.3.8 Dynamics of Air-Water Gas Exchange

- B. Kerman and J. Ridal

Air-water gas exchange is a major pathway for the global transport of persistent organic pollutants. The first part of a two-pronged approach to elucidating the processes and mechanisms of gas exchange in natural waters involves the weekly measurement of dissolved inorganic gases (oxygen, nitrogen and argon) in surface and deep waters of Lake Ontario.

The shipboard program commenced in April 1993 with the co-operation of scientists and technical staff from the Canada Centre for Inland Waters and the Ontario Ministry of Natural Resources. The April start-up allowed the measurement of the effects of the spring over-turn and early thermocline formation to gas dynamics in Lake Ontario. This program continues until late October so that changes to dissolved gas concentrations during the fall over-turn will also be measured. Concurrent measurement of three inorganic gases enables us to estimate the relative importance of physics processes to establishing dissolved oxygen levels compared with biological processes. An improved understanding of factors affecting gas transfer in Lake Ontario supports the development of models for air-water gas exchange of environmentally persistent pollutants.

The second aspect of our gas exchange program is an investigation into the transfer of HCHs (i.e., lindane and its isomers) between Lake Ontario and its atmosphere. Simultaneous air and water HCH measurements are carried out weekly from the same shipboard platforms used in the dissolved inorganic gas study, allowing direct comparison of HCH gas exchange with that of the more readily measured inorganic gases. The weekly shipboard measurements of atmospheric HCH values over Lake Ontario will provide a valuable data set to which regional land-based atmospheric measurements can be compared. As well, HCH concentrations are determined weekly in water samples from depth profiles at one station in central Lake Ontario. Such concentration depth profiles are useful for monitoring the invasion/evasion of seasonal atmospheric HCH signatures to the deeper waters of Lake Ontario, as well as for providing information regarding possible sinks of HCHs in the water column.

2.3.9 Gas-Particle Distribution of PCBs in Ambient Air
- T. Bidleman and R. Falconer

This project was started at the University of South Carolina and is continuing under support from the U.S. Environmental Protection Agency. The goals are to determine levels of coplanar polychlorinated biphenyls (PCBs) in ambient air in Chicago, and to test the hypothesis that ortho-chlorine substitution patterns affect the partitioning of PCB congeners to aerosols. Greater fractions of toxic non- and mono-ortho (coplanar) PCBs on particles may enhance their wet and dry deposition.

The present research forms a major part of a Ph.D. dissertation in chemistry, and consists of: 1. predicting the adsorption of PCBs to aerosols from vapour pressures of individual congeners, using the Junge-Pankow model; 2. determining total and coplanar PCBs in field samples collected in Chicago during winter 1988 and summer 1989; and 3. carrying out laboratory experiments to compare partitioning of PCBs having different numbers of ortho-chlorine to Chicago urban air particulate matter.

Measurements of the apparent particle/gas distribution of PCBs in Chicago air with a filter-polyurethane foam sampler showed an increase in particulate percentages for the toxic non-ortho PCBs 77 and 126, and mono-orthos 118 and 105 when compared to multi-ortho PCBs within the same homologs. These congeners contribute substantially to dioxin-type toxicity (expressed as toxic equivalents, TEQ) in fish, marine mammals, and aquatic birds. Levels of these congeners in Chicago air, in the fg/m^3 - pg/m^3 range, are an order of magnitude or more above those found in air from the rural Great Lakes, showing that urban areas near the lakes are significant sources of coplanar PCBs.

Laboratory experiments in which Chicago aerosols are equilibrated with vapor-phase PCBs clearly show the influence of ortho-chlorine substitution on particle/gas distribution. Using eight model compounds having 0 - 3 ortho-chlorines, it was found that the fraction sorbed to particles increased in the order: 2-3<1<0. Thus predictive models, field collections, and laboratory experiments all confirm the "ortho-effect" hypothesis.

2.3.10 PAH Transformations
- D. Lane and H. Tang

The reaction chamber built at York University has been equipped with basic instrumentation necessary to follow the reactions of vapour phase polycyclic aromatic hydrocarbon (PAH) with the OH radical. The concentration of the PAH (naphthalene) in the chamber is measured by an on-line HP 5890 Series II gas chromatograph. The concentration of the naphthalene can be measured approximately every 12 minutes. In addition to the chromatograph, a NOx monitor and a chemiluminescent ozone monitor are available to determine both the NO and ozone concentrations in the chamber.

Significant results have been obtained from the initial chamber studies. The reaction of the OH radical with naphthalene has been investigated, and, to date, 14 products have been isolated and identified. Numerous others have been tentatively

identified. Many of these products have never been reported previously.

One of the objectives of this program was to establish collaborative links with other universities and industry. At present, scientists from the universities of York, Guelph and McMaster, and from NovaMann Laboratories have become involved with the activities of the chamber.

2.3.11 Aerial Application of Pesticides
- R. Mickle

In May, AES collaborated with the Forest Pest Management Institute in a research spray program for the gypsy moth in the Peterborough area using a new virus product which is a natural virus to the gypsy moth but with no known impact on other species. AES's involvement included meteorological measurements during the spray program, and the logging of the aircraft position and relevant parameters during the actual spray.

A subsequent priority list for improvements to the FSCBG model includes input capabilities for directly linking the output from aircraft loggers so that the model can be used to predict the resultant deposit and off-target movement of pesticide during an aerial application. Modifications to the next version of FSCBG will allow for modelling actual spray lines utilizing line-averaged spray data on aircraft position, height, flows and meteorology.

A final report on the New Mexico experiment entitled "Strategy for Reducing Drift of Aerially Applied Pesticides" has been completed. The experiment was designed to determine the magnitude of differential drift and deposit from upwind and downwind atomizers under conditions representative of operational spraying. For all trials the drift from the downwind wing exceeded the drift from the upwind wing confirming earlier experiments using the AES ARAL system. Deposit from the upwind wing was on average 1.5 times that from the downwind wing. There was a weak dependence on background turbulence with increased preference for deposit from the upwind wing with decreased turbulence (i.e., greater stability). No correlation with aircraft height was found.

The results have quantified the advantages of spraying from the upwind wing, both in terms of the deposit of the small droplets and hence off-target drift. Recommendations are being made to aerial applicators that pesticides should be ported to the upwind wing when spraying upwind close to environmentally sensitive areas.

2.3.12 Toxaphene in the Arctic
- T. Bidleman

This work was started at the University of South Carolina and is continuing at AES. The goals are: 1. to determine levels of chlorobornanes (CHBs = toxaphene) in air and water from arctic and other remote regions; 2. to examine the complex chromatographic profiles of CHBs in air, water and biological specimens for evidence of physicochemical fractionation vs. metabolic transformations; 3. to determine vapor pressures and Henry's law constants of CHBs; and 4. to compare the air-water gas exchange characteristics of CHBs and hexachlorocyclohexanes (HCHs).

Field work was carried out at Resolute Bay, N.W.T., and on a joint Russian - U.S. cruise to the Bering and Chukchi seas (BERPAC-93). It was found that the levels of CHBs in air and water at Resolute Bay are lower by a factor of 2-3 than arctic values in the mid-1980s. Congener distributions of CHBs in air and water are similar. The surface water of Resolute Bay was 26% saturated with CHBs, relative to equilibrium with CHBs in air, implying that the net gas flux was from air to water. This tentative conclusion is based on extrapolation of the only published Henry's law constant for the toxaphene mixture from 20°C to -1°C.

Summertime levels of HCHs in arctic air have dropped three-fold since 1988-90, whereas surface water concentrations have changed by only about 20%. The sudden decrease in atmospheric concentrations agrees with measurements from the Alert monitoring program and data from the Norwegian station at Spitzbergen. As a consequence, surface water at Resolute Bay and the Bering-Chukchi seas is now oversaturated with α-HCH during the summer (160-200%), indicating volatilization -- a reversal of the flux direction from the 1980s. The first evidence of microbial breakdown of α-HCH in arctic waters was found at Resolute Bay and nearby Amituk Lake, by examining the ratio of the two optical isomers (enantiomers).

2.3.13 Modelling Global-Scale Transport of HCHs
- T. Bidleman

The objective is to compile and review environmental measurements in air and water and physicochemical properties of hexachlorocyclohexanes (HCHs) for use in a global model of HCH transport and cycling. Over 1700 measurements of HCHs in northern and southern hemisphere air, and 600 measurements in

the major oceans of the world have been compiled, along with coordinates, dates of collection and literature citations. In examining the long-term trend in arctic air HCH concentrations, it is revealed that there was a striking decline -- from 900 pg/m^3 in 1979 to 100 pg/m^3 in 1993. These changes appear to have been stepwise, with a major decrease after 1982 and another 3-fold drop after 1988-90. Shut-downs of technical HCH production by one or more major-use countries is likely to be responsible for this trend.

2.3.14 Northern Contaminants Monitoring

- L. Barrie, in cooperation with P. Fellin and D. Muir

Since January 1992, measurements of persistent organic pollutants, including herbicides, pesticides, synthetic industrial compounds and polycyclic aromatic hydrocarbons (PAHs), have been made on a weekly basis in the Canadian and Russian Arctic. The objective is to measure the occurrence of these substances in the Arctic atmosphere for a period of several years thereby providing insight into sources, transport, transformation and surface exchange processes, as well as data for validation of models of toxics pathways in the northern environment.

This research was supported by the Arctic Environmental Strategy Northern Contaminants Green Plan Program and the Department of External Affairs.

Hi-volume air samplers placed at Alert, N.W.T., Tagish, Yukon, and at the mouth of the Lena River on Dunay Island in Russia were used to collect particulate and gaseous fractions of these airborne pollutants on filters. The filters were subsequently extracted in organic solvents and analyzed for 80 organochlorines and 20 PAHs by gas chromatographic techniques.

Results from the first year of measurements at Alert are the first continuous measurements over all four seasons that have been made in the north. Figure 1 shows the concentrations of DDT for 1992. DDT is a pesticide which has been banned in many parts of the world because of the effects it was having on wildlife reproduction, particularly that of birds. These results show that it is present in the Arctic atmosphere particularly during the period January to May when Arctic haze pollution is greatest. Thus, it is still being released to the atmosphere somewhere on the globe and is reaching the Arctic via long range transport through the atmosphere.

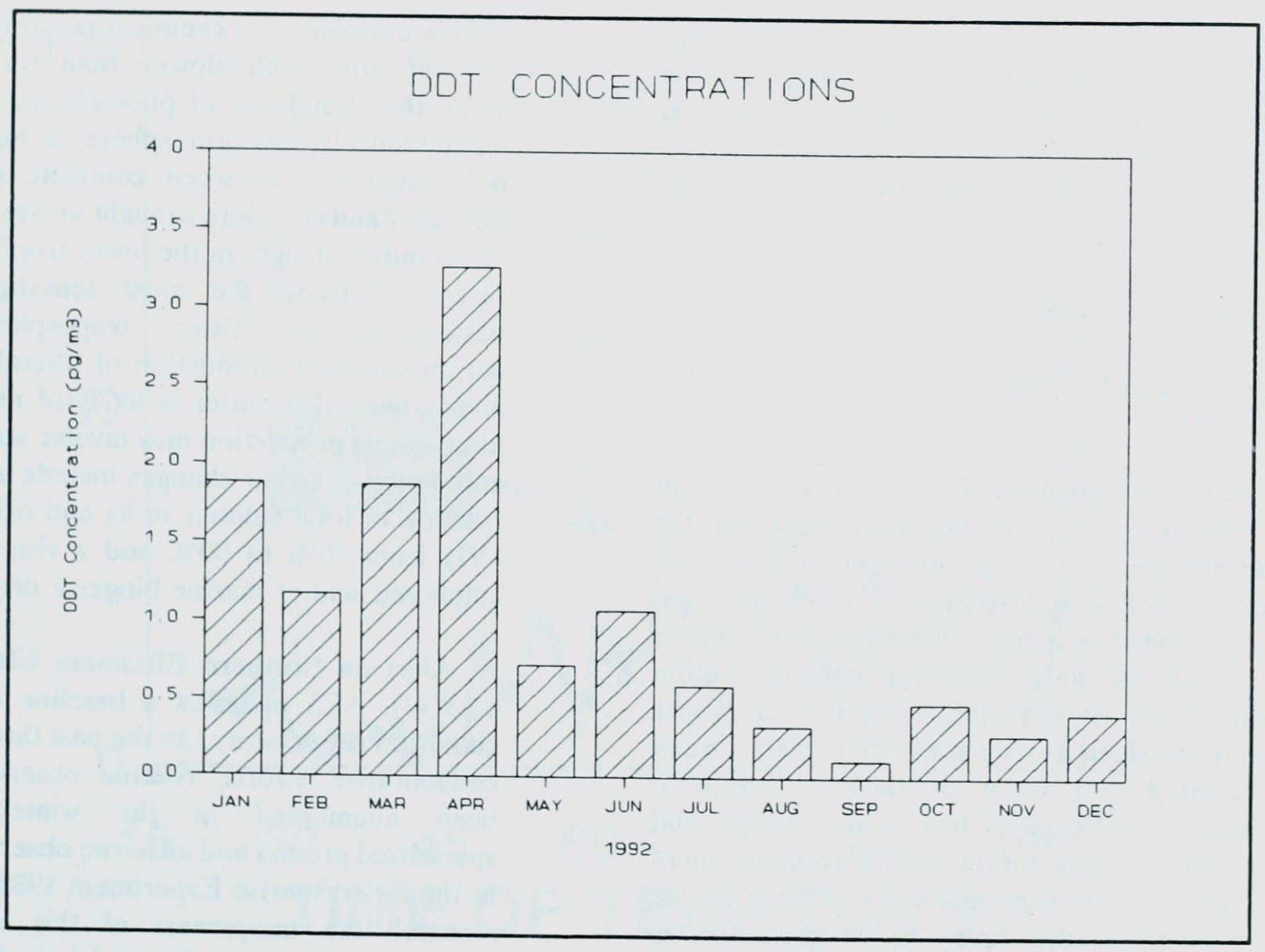

Figure 1: DDT in air at Alert for 1992

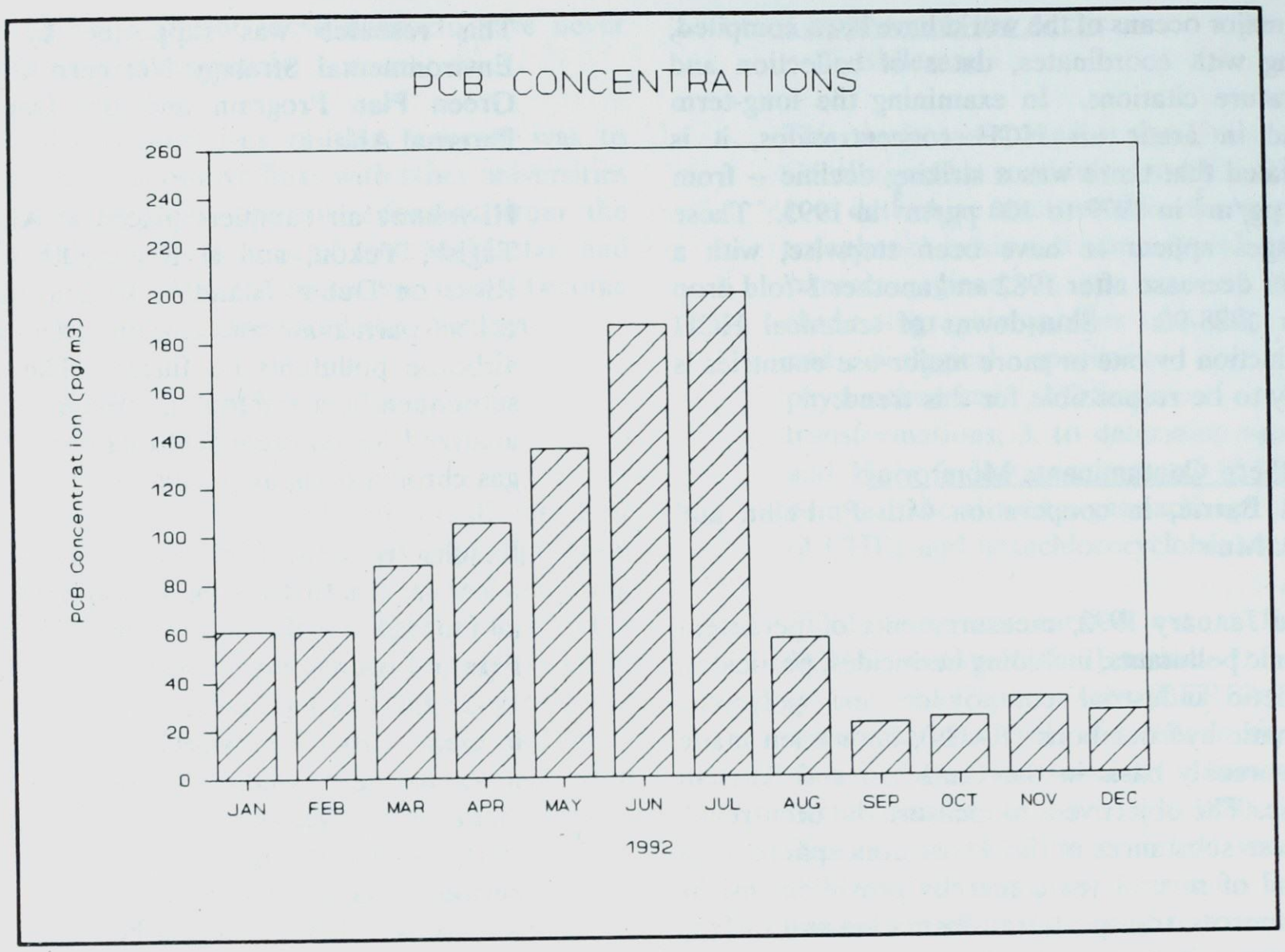

Figure 2: PCBs in air at Alert for 1992

Figure 2 shows the seasonal variation of total airborne polychlorinated biphenyls (PCBs) that are a synthetic industrial chemical. It peaks in summer in the Arctic atmosphere but is also present during the Arctic haze months of January to May.

2.4 CLIMATE CHANGE

2.4.1 Polar Sunrise Experiment 1992
- L. Barrie

The Arctic troposphere (0 to 8 km) plays an important role in environmental concerns for global change. It is a unique chemical reactor influenced by human activity and the Arctic ocean. It is surrounded by industrialized continents that in winter contribute gaseous and particulate pollution (Arctic haze). It is underlain by the flat Arctic ocean from which it is separated by a crack-ridden ice membrane 3 to 4 m thick. Ocean to atmosphere exchange of heat, water vapour and marine biogenic gases influence the composition of the reactor. From September 21 to March 21, the region north of the Arctic circle goes from a completely sunlit situation to complete darkness and then back to continuous sunlight. At the same time the lower troposphere is stably stratified. This hinders vertical mixing.

In this environment, chemical reactions involving sunlight are much slower than further south. Thus, the abundance of photochemically reactive compounds in the atmosphere is high prior to polar sunrise. Between complete darkness in February and complete sunlight in April, a number of chemical changes in the lower troposphere take place. Perhaps the most sensational is the destruction of lower tropospheric ozone accompanied by production of filterable bromine and iodine. The latter is likely of marine origin although its production may involve anthropogenic compounds. Other changes include a shift in the fraction of total sulphur in its end oxidation state (VI) from 50% to 90% and a rise in methane sulphonic acid of marine biogenic origin.

At Alert on Northern Ellesmere Island (82.5°N, 62.3°W), AES operates a baseline tropospheric chemistry observatory. In the past through various collaborative efforts, routine observations have been augmented in the winter/spring by specialized ground and airborne observations, such as the Polar Sunrise Experiment 1988, which have revealed the uniqueness of this observational location and season in studying chemical and physical processes in the winter northern hemispheric troposphere. The results of the study were reported in last year's annual report. The

periodic disappearance of lower atmospheric ozone at polar sunrise associated with particulate Br production is shown in Figure 3. Of note is the strong depletion of ozone after April 1 (day 92) accompanied by peaks in the particulate bromine. Approximately 17 papers have been accepted for publication in a special section of the Journal of Geophysical Research.

2.4.2 Boreal Forest Study (BOREAS)
- N. Trivett and D. Ernst

An 8-level CO_2/H_2O profile system was designed and installed at the experimental site for the Boreal Forest Study. This system has operated well over the winter period and produced some very interesting and unexpected results indicating CO_2 emissions from the soil during the winter.

2.4.3 Canadian Baseline Program
- N. Trivett

The atmospheric mixing ratios of carbon dioxide and methane from January 1988 to December 1993 are plotted in Figures 4 and 5, respectively, along with the seasonal cycle and long term trend.

These data show that there are significant seasonal variations, that the mixing ratios were initially increasing, and that, during 1993, the mixing ratios of methane decreased while carbon dioxide remained almost constant. The data also show that the late fall and winter periods are much more variable compared to the spring and summer periods, and that the carbon dioxide and methane are highest during late fall to winter and the lowest during the summer.

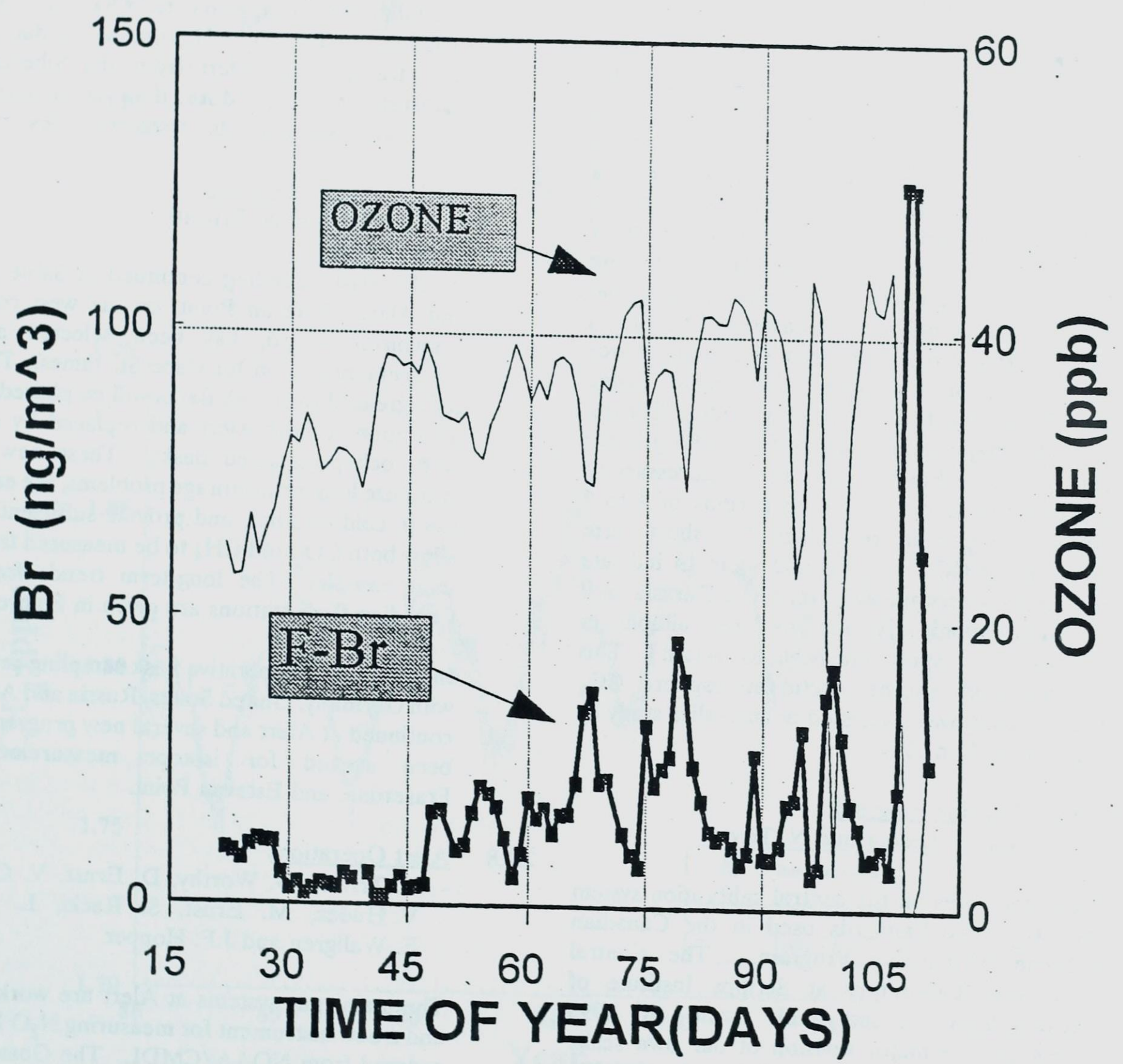

Figure 3: Observed daily concentrations of ozone and bromine at Alert in 1992

The seasonal cycle is mostly due to the seasonal variations in the biological activity and, in the case of methane, due to changes in the photochemical sink. The decrease in carbon dioxide is primarily due to the uptake of carbon by vegetation whereas the decrease in methane is primarily due to the chemical destruction by the reaction of methane with the hydroxyl (OH) radical. Even though the large decrease in methane observed during the latter half of 1992 and early 1993 (see Figure 5) was quite obvious, the concentration of carbon dioxide remained relatively constant indicating that the sources for methane reaching the Arctic are different from those for carbon dioxide. There has been considerable speculation as to the cause of the methane decrease, such as the decrease in industrial activity in Russia, but this cannot account for the general decrease evident in all the northern hemisphere data.

The interpretation and synthesis group under K. Higuchi has completed studies examining the sensitivity of the land biota to climate change using the 2-D global carbon cycle/climate coupled model. It was found that the biogeochemical response of the carbon in the land biosphere is more sensitive to changes in the carbon content of the atmosphere than to changes in the climate parameters. The results of the dynamic regional model used to simulate the transport of pollutants into the Arctic atmosphere from temperate source regions were consistent with previous studies using 5-day back trajectories indicating middle Eurasia to be the major source region for anthropogenic CO_2 at Alert. Furthermore, it was necessary to integrate the model over time periods of 4 to 5 weeks in order to reproduce the short term variations of CO_2. This would seem to indicate that the CO_2 accumulates over arctic Eurasia until the meteorological conditions are suitable to produce the rapid transport to Alert. This inhomogeneity in the Arctic atmosphere CO_2 concentration was suggested in an earlier study by Higuchi et al. in 1987.

2.4.4 Carbon Dioxide Program
- D. Ernst, L. Leeder and N. Trivett

Work continues on the central calibration system for CO_2-in-air standards used in the Canadian Baseline Monitoring Program. The Central Calibration Laboratory at Scripps Institute of Oceanography revised their scale in 1993 necessitating a major revision of our own scale. Figure 4 indicates the infrared (NDIR) measurements of carbon dioxide at Alert averaged over 6 hours with the long-term trend and seasonal cycle shown.

2.4.5 Methane Program
- D. Worthy and M. Ernst

Development work continues to improve the analysis of methane and carbon dioxide from both the in-situ and grab flask samples. The precision of the gas chromatographic (GC) CO_2 measurements has improved to the point where it may be possible to eliminate the NDIR flask measurements in the near future. Figure 5 indicates the GC measurements of methane averaged over 6 hours.

2.4.6 Freon Program
- D. Worthy and M. Ernst

The GC system for F-11, F-12 and F-113 has been operating at Alert for over a year. Preliminary inspection of the data shows surprising short-term variability which appears to relate to similar variations in the CO_2/CH_4 time series due to air mass transport to Alert from the Siberian or Eurasian sectors. More data is required to determine annual trends or season cycles.

2.4.7 Flask Sampling Program
- V. Hudec and N. Trivett

Weekly flask sampling continued at Sable Island and Alert. Estevan Point, on the west coast of Vancouver Island, has been selected as the replacement station for Cape St. James. The old style greased stop cock flasks will be phased out at all stations except Alert and replaced by double stop cock pressurized flasks. These new flasks minimize long-term storage problems, are easier to use in cold weather, and provide sufficient gas to allow both CO_2 and CH_4 to be measured from the same sample. The long-term trends from the Canadian flask stations are given in Figure 6.

International cooperative flask sampling programs with Germany, United States, Russia and Australia continued at Alert and several new programs have been started for isotope measurements at Fraserdale and Estevan Point.

2.4.8 Alert Operations
- N. Trivett, D. Worthy, D. Ernst, V. Chorney, V. Hudec, M. Ernst, S. Racki, L. Leeder, E. Wallgren and J.F. Hopper

The major gas systems at Alert are working well and a new instrument for measuring N_2O has been ordered from NOAA/CMDL. The Gossen PAH analyzer installed at Alert worked well with no downtime in contrast to the CN counters which continue to be troublesome.

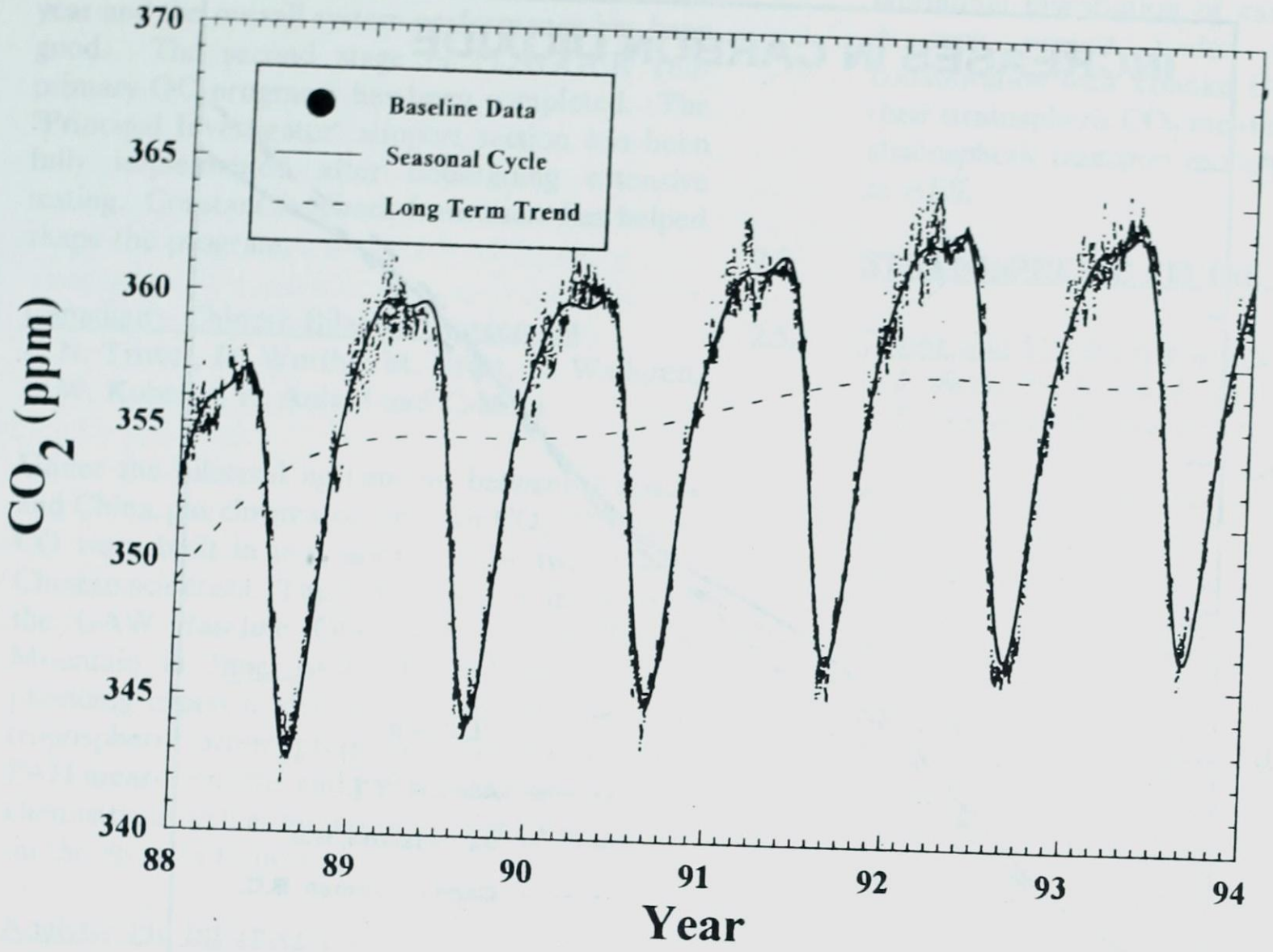

Figure 4: Carbon dioxide concentrations at Alert

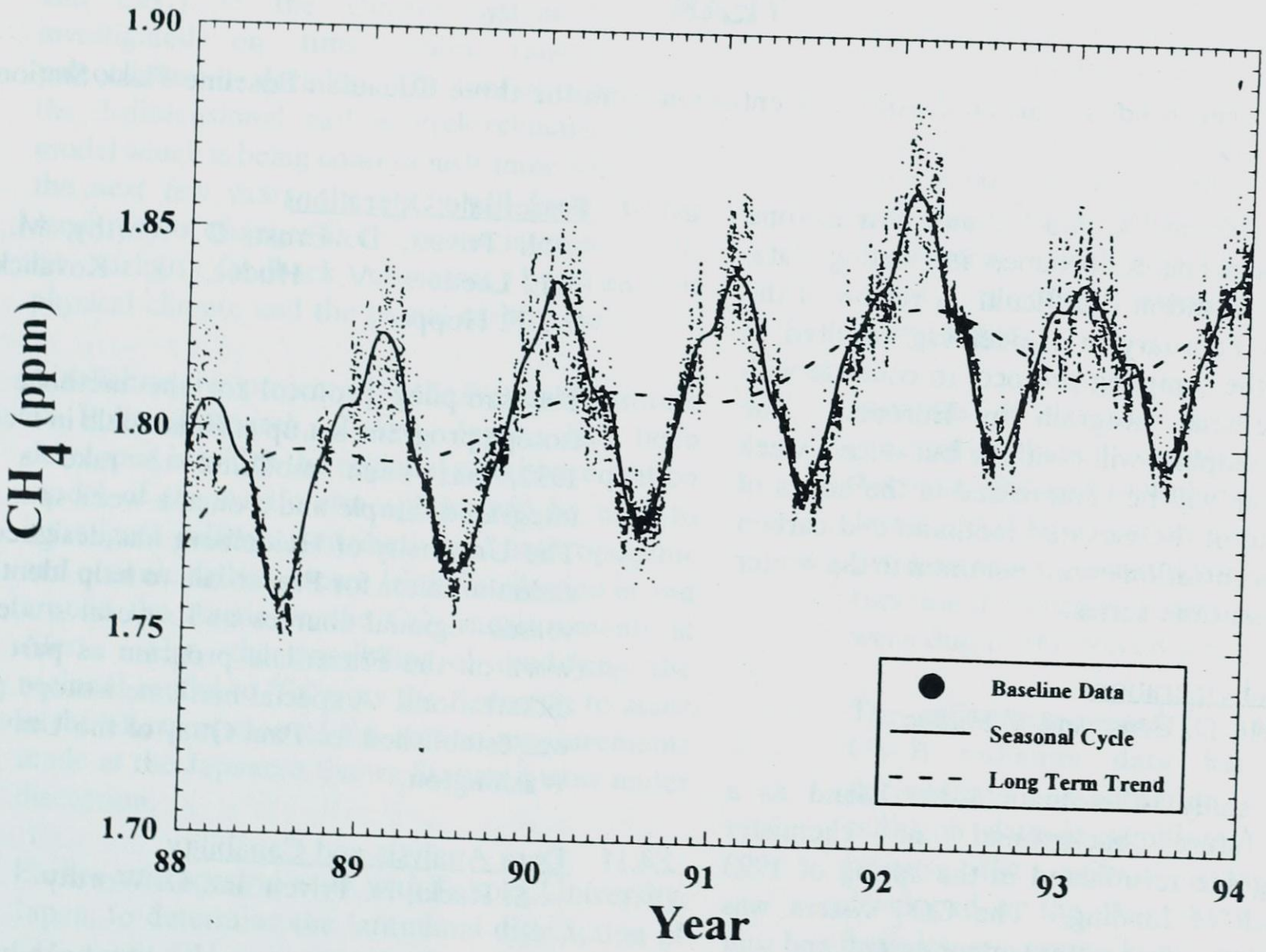

Figure 5: Methane concentrations at Alert

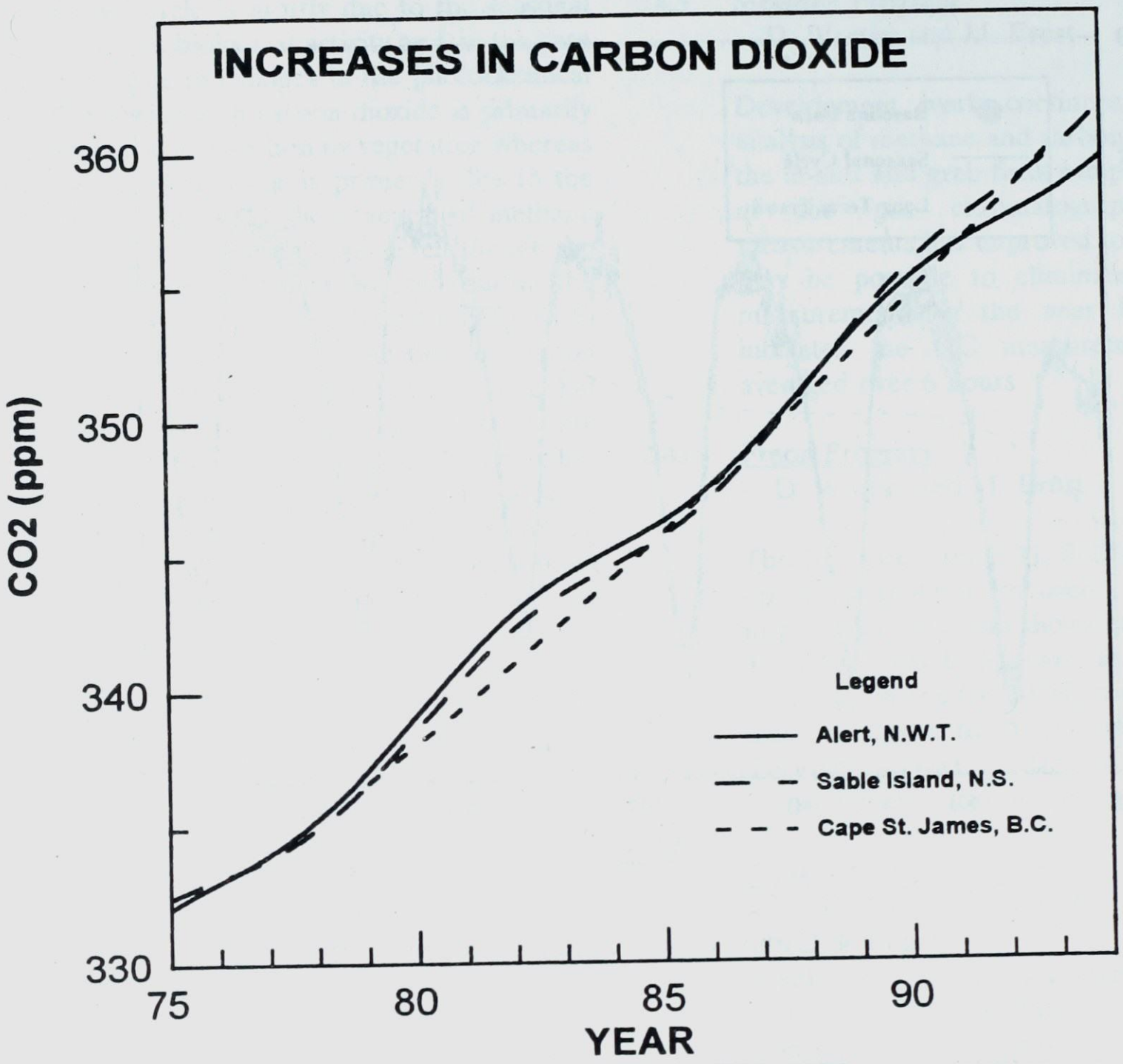

Figure 6: Long-term trends in carbon dioxide concentration from the three Canadian Baseline Flask Stations.

The Alert methane ^{14}C and ^{13}C and ^{85}Kr isotope programs continue to produce interesting data, though interpretation is difficult. A review of the program in February in Heidelberg resulted in changes to the sampling protocol to coincide with a new methane program in Europe. The integrated sampling will continue but once a week a special tank will be compressed in the hopes of catching one of the elevated methane and carbon dioxide concentration events common to the winter time baseline time series.

2.4.9 Sable Island Operations

- N. Trivett, D. Ernst and V Hudec

The pilot study to evaluate Sable Island as a possible future background air chemistry monitoring site terminated in the spring of 1993 due to lack of funding. The CO_2 system was modified to measure water vapour as well and sent to the BOREAS study. The Sable Island program is in serious trouble with the possible closure of the DOE Aerology Station.

2.4.10 Fraserdale Operations

- N. Trivett, D. Ernst, D. Worthy, M. Ernst, L. Leeder, V. Hudec, J. Kovalick and J.F. Hopper

The sampling protocol for the methane carbon isotope program, set up at Fraserdale in December 1992, has been modified to take a weekly integrated sample and a once-a-week spot sample. The University of Heidelberg has designed a new radon monitor for Fraserdale to help identify local versus regional sources and several students will work on the Fraserdale program as part of their dissertations. A special methane isotope program was established for Paul Quay of the University of Washington.

2.4.11 Data Analysis and Capability

- S. Racki, N. Trivett and D. Worthy

The Novell Netware server has been upgraded with more memory and user hard disk storage to facilitate the analysis of the Alert and Fraserdale

data sets. Downtime has been minimal over the year and the overall system performance has been good. The second stage of FLAGGER (our primary QC program) has been completed. The "Principal Investigator" support section has been fully implemented after undergoing extensive testing. Constant feedback from users has helped shape the program.

2.4.12 Canadian - Chinese Bilateral Agreement

- N. Trivett, D. Worthy, M. Ernst, E. Wallgren, W. Kobelka, K. Anlauf and C-M Li

Under the bilateral agreement, between Canada and China, gas chromatographs for CO_2/CH_4 and CO were built in our laboratory by two visiting Chinese scientists. This system will be installed at the GAW Baseline Observatory on Walliguan Mountain in June 1994. In addition, AES is providing expert advice and help for the station's tropospheric ozone program, black carbon and PAH measurements, and precipitation and aerosol chemistry, as well as meteorological measurements on the 86 m tall tower.

2.4.13 Analysis and Interpretation

- K. Higuchi, D. Chan and K. Yuan

The study of the interaction between the physical and the global biogeochemical carbon cycle (CO_2 and CH_4) of the climate system is being investigated on time scales ranging from paleoclimate to decades. The tool of the study is the 2-dimensional carbon cycle/climate-coupled model which is being continuously improved. Over the next few years, the study will focus on the sensitivity of changes in the ocean internal mixing on various feedback processes between the physical climate and the global carbon cycle.

A collaborative project with the National Institute of Polar Research, Tokyo, Japan, has been developed in which the regional primitive equation model of the Arctic atmosphere will be used to investigate relative contribution of anthropogenic and oceanic carbon source/sink distribution in and around the Arctic on the CO_2 measurements at Alert. Also, the possibility of modifying the regional model to "fit" over the Antarctic to assist in the interpretation of the carbon measurements made at the Japanese Syowa Station is now under discussion.

Earlier collaborative work with Tohoku University, Japan, to determine the latitudinal distribution of CO_2 and CH_4 sources and sinks has been extended. The basic approach of the study is to force the model calculation to fit the observed latitudinal distribution of carbon isotopic values. A new project under development is a collaboration with Tohoku University to interpret their stratospheric CO_2 measurements, using a 2-D stratospheric transport model originally developed at AES.

2.5 STRATOSPHERIC STUDIES

2.5.1 Ozone and UV-B Monitoring

- J. Kerr, W. Clark, J. Bellefleur, F. Karpenic, D. Tarasick, E. Wu and R. Hoogerbrug

Automatic data reporting from the field stations was implemented in May 1993 and the data are distributed to a wide area network which is used for the communication of operational meteorological data. This allows immediate access to preliminary ozone and ultraviolet-B (UV-B) radiation measurements from all Canadian stations. The data are also accessed automatically by the AES Canadian Meteorological Centre for use in the UV Index forecast and Ozone Watch programs which have been operational since 1992.

Other countries have expressed interest in implementing UV Index programs to advise the public on present and future UV levels. Many requests have been received for guidance in the setting up of ozone and spectral UV-B radiation monitoring capabilities and in the implementation of an UV Index program.

The Canadian stations reported low values for stratospheric ozone in 1993. These findings were consistent with measurements from satellite instruments as well as ground-based measurements made in other countries in the northern hemisphere.

Analysis of the record of the Brewer UV-B spectral radiation measurements for Toronto between 1989 and 1993 showed significantly higher levels of UV-B radiation during 1993 than during previous years. Quantification of the changes as a function of wavelength demonstrated the increases were due to the record low ozone values.

The calibration record for the Toronto spectral UV-B radiation data has been fairly well documented. Calibration of the field UV-B radiation data is significantly more challenging because the calibration facilities have been developed at the Downsview site and the field facilities are normally not moved. Development and testing of appropriate equipment and procedures for accurate field calibration is being carried out.

2.5.2 Arctic Stratospheric Observatory

- H. Fast, K. Nassim, W.J. Clark, A. Ullberg, J.J. Bellefleur, F. Karpenic and R.H. Hoogerbrug

The first full winter campaign to study the north polar vortex atmosphere at Eureka began in September 1993 and ended in March 1994.

In collaboration with the Meteorological Research Institute (MRI), atmospheric absorption spectra were recorded with the Bomem solar interferometer. These spectra were obtained in two periods: September 22 to October 13, just before the onset of polar night, and February 23 to March 30, just after polar sunrise. The data is expected to yield vertical column densities of HCl, HF, HNO_3, NO and N_2O.

The Differential Absorption Lidar (DIAL) was operated by the Institute of Space and Terrestrial Science (ISTS) from the beginning of November to the end of March. Vertical profiles of ozone, temperature and aerosols were obtained on clear nights in the altitude range 15 to 70 km. The other LIDAR system, designed to measure vertical profiles of Arctic haze as well as Polar Stratospheric Cloud (PSC), was operated jointly by the MRI and the Communications Research Laboratory (CRL) of Japan. Observations were made on clear nights from the beginning of December to the end of February.

Under the auspices of the Canadian Network for Space Research, a number of instruments operated continuously from October to March. Their main function was to monitor the temperature and the winds in the region above 80 km, as well as record auroral phenomena. An experimental Brewer spectrophotometer measured the ozone column, using the moon during polar night. The frequency of ozonesonde launches from the Eureka weather station was increased from one per week to three per week, during the period from December to the end of February when both LIDAR systems were operating simultaneously.

2.5.3 Infrared Measurements Development

- H. Fast, K. Nassim, W.J. Clark, A. Ullberg, J.J. Bellefleur, F. Karpenic and R.H. Hoogerbrug

Due to other priorities, the annual Canadian Ozone Experiment (CANOZE) did not take place at Alert this winter. However, the balloon-borne radiometer, which is flown on these campaigns to determine the vertical profile of nitric acid vapour, underwent further testing and an overall assessment was begun in order to improve future measurements.

Under an AES contract to Bomem Inc., the hardware and software of the higher resolution balloon-borne interferometer was upgraded. In November the instrument was installed at CARE, where it has been used to make ground-based atmospheric absorption measurements on an experimental basis.

2.5.4 Aircraft and Space Experiments

- C.T. McElroy, C. Midwinter, R. Hall and D. Barton

The SunPhotoSpectrometer (SPS), which was developed by the AES to fly on the US Space Shuttle with Steve MacLean, was adapted to fly on the NASA ER-2 high-altitude research aircraft in 1992 in response to an invitation from NASA. It was included in the ER-2 chemistry research payload during the Stratospheric Photochemistry, Aerosol and Dynamics Expedition (SPADE) in May 1993 providing information about the radiation environment of the aircraft during flight. The instrument provides data which allows the calculation of photochemical reaction rates and the direct measurement of the albedo of the earth-atmosphere system below the aircraft. The flights were funded by the NASA High Speed Research Program and were aimed at developing a more comprehensive understanding of midlatitude stratospheric chemistry so that the impact of the operation of proposed, advanced supersonic transports can be accurately assessed.

Much of the year was spent developing new processing algorithms to handle the large amount of information collected and in producing a preliminary analysis of the whole data set. Interim results from the AES Composition and Photochemical Flux Measurement (CPFM) were published on a CD-ROM.

During the SPADE flight series, AES was asked to participate in the 1994 NASA Antarctic vortex chemistry research campaign. A special issue of Geophysics Research Letters will be produced in 1994 to report the results from the experiments which were conducted during the SPADE project.

Participation in the ER-2 chemistry program has allowed AES scientists and the Canadian co-investigators on the project to have unique access to all of the data collected by the whole science team. The comprehensive instrument package which is flown on the ER-2 collects information on more than a dozen chemical species which are

crucial to the chemistry of ozone in the stratosphere. Several investigations of research issues important to the understanding of the chemistry of the stratosphere are now underway using the data from the CPFM experiment and the larger SPADE data set.

Work also continued toward the completion of the codes needed to analyze the results from the 1992 Shuttle Flight. The publication of the results from the successful flight of SPEAM II will lead to additional space flight opportunities aimed at the long-term monitoring of stratospheric ozone and ozone photochemistry.

2.5.5 National Atmospheric Radiation Centre

- L.J.B. McArthur, T. Grajnar, A. Arama, E. Wu and R.H. Hoogerbrug

The number of instruments the solar radiation laboratory calibrates continues to increase as more government and private companies utilize our service. These calibrations include both routine indoor and specialized outdoor calibration. Effort has been placed in the automating of the black-body calibration facility which is used in the calibration of net-radiometers and pyrgeometers. With the need for increased efficiency and the growth in the number and type of calibrations performed, calibration automation is a priority over the next several years.

Experimental work was completed on a cold chamber calibration apparatus. The testing of instrument responsivity changes as a function of temperature will become part of the routine instrument calibrations of the laboratory in 1994. The experimental work indicates that most instruments, even when designed to operate through extremes in temperature, require further corrections before the data can be used in determining trends.

The laboratory participated in an international comparison of pyrgeometer calibration procedures as part of the World Climate Research Program, Baseline Surface Radiation Network. Results of the comparison of the dozen laboratories which participated will be discussed in Zurich, September 1994.

Also, as part of the Baseline Surface Radiation Network, the first Canadian network station became operational in March 1994, 20 km south of Regina, Saskatchewan. The station is one of approximately 20 sites globally using precision instruments and high temporal resolution sampling to be able to measure changes in the incoming radiation fluxes. The data obtained from the site will be used in the calibration of satellites and long-term trend analyses. The establishment of the site has resulted in the provision of real-time ozone and UV-B radiation measurements to southern Saskatchewan.

As part of the International Energy Agency, Solar Heating and Cooling Programme, Task 17, the laboratory participated in an international comparison of spectrometers in Munich, Germany during August/September 1993. The Canadian instruments used during the comparison were a Brewer Mk III, a double monochromator instrument, and a ground-based prototype of the SPS shuttle instrument. Preliminary results indicate that the Mk III Brewer is the instrument of choice for the measurement radiation in the ultra-violet wavelength region.

The Department of Environmental Studies, University of Calgary, has been under contract to install and operate a daylight measurement station as part of the Commission Internationale d'Éclairage International Daylight Measurement Programme. The station has been producing quality data since the summer of 1993. The research efforts have now turned to a better understanding of the calibration and characterization of the instruments. Collaboration with the National Research Council has resulted in the establishment of an illuminometer calibration centre at the university.

2.5.6 Dynamic Global Ozone Analysis and Forecasts

- A. Dastoor

Using the Canadian global forecast model as a starting point, techniques are being developed to forecast total column ozone thickness. Currently, a statistical procedure "perfect prog" is used for a diagnostic ozone forecast. The total ozone forecast is then used to generate UV flux values for Canada's UV Index program. The objective is to develop a dynamic ozone analysis and forecasting system. The system will be used to improve UV Index forecasting, stratospheric circulation simulation, and to study ozone-radiation interaction and ozone chemistry.

The ozone field was incorporated in the Canadian global spectral forecast model as a passive tracer. A 3-dimensional ozone initialization scheme was developed for the global model. The scheme uses satellite total ozone and objectively analyzed meteorological fields as inputs to generate the vertical distribution of ozone on a global scale. Initial ozone forecasts and their verifications with

the observed 3-D Brewer and the 2-D satellite data were performed. The model is producing encouraging results for the total column ozone forecasts. An ozone variational analysis system is also being developed.

2.6 CORE RESEARCH

2.6.1 Flow Over Complex Terrain

- J.L. Walmsley and W. Weng

In collaboration with Dr. M. Claussen, Max-Planck-Institut für Meteorologie, Germany, a modification was implemented in the new Planetary Boundary Layer (PBL) Resistance Law formulation.

The MS-Micro/3 model was applied to Roundtop Mountain, near Sutton, Quebec to produce wind fields to be used in estimating acid deposition from fog. This project is being undertaken in collaboration with Prof. H.A. Bridgman, University of Newcastle, Australia, and Dr. R.S. Schemenauer (ARMP). Papers have been written on wind field estimation and on fog deposition calculation.

Improvements to the MSFD-PC software were made in collaboration with Prof. S.R. Karpik, University of Toronto. All model equations and code were thoroughly checked with the MAPLE symbolic algebra software; formulation for the top boundary conditions is being revised. Publication of this work has been delayed until 1994/95 because improvements were more extensive and thorough than anticipated.

Work was begun on a joint project with York University and Dr. Keith Ayotte (on leave at NCAR) to compare three models in the MSFD family using the 1983 Askervein dataset for verification. The models involved are MSFD-PC, NLMSFD and MSFD-PBL. MSFD-PC's linearized equations make it suitable for terrain slopes up to about 1:3. Recently a *nonlinear* extension of the model (NLMSFD) was developed at York University. This model enabled the restriction on terrain slopes to be relaxed, making it applicable in more rugged terrain than its linear predecessor. Both MSFD-PC and NLMSFD exclude effects, such as wind-turning and a gradual approach to geostrophic conditions with increasing height in the Planetary Boundary Layer. MSFD-PBL is a new model that attempts to incorporate those features.

Revenue generation continued at a slightly higher rate than last year ($2,670 total). The MS-Micro/3 model code was sold to 7 groups in 5 countries. The new MSFD-PC model code was sold to 5 groups in 4 countries. The "Guidelines" program for estimating wind speed in complex terrain was distributed to 15 groups in 5 countries. The "Wind Profile over Sea" and "Wind Correlation" programs were sold to 4 groups in 3 countries. In January 1994, a Software Distribution Agreement was signed by AES and a consulting firm, whereby software on wind flow in complex terrain developed in-house will be marketed on our behalf and for which the Branch will directly receive 50% of the revenue.

2.6.2 Mesoscale Modelling

- Y. Qi

Beginning in December 1993, a 2-D second-order turbulence-closure mesoscale model for flow over mountains was implemented. Efforts are now being made to extend the model to three dimensions. Studies will be conducted on the interaction between mesoscale mountain waves and the planetary boundary layer (PBL).

2.6.3 Wind Energy

- J.L. Walmsley

Activities on the **Wind Resources Assessment in Southwestern Saskatchewan Steering Committee**, jointly sponsored by SaskPower and Natural Resources Canada, involved evaluation of contract bids and advice on monitoring the contract.

A contract titled "Testing the Accuracy and Methods of Applying the Wind Correlation Model" was let. Due for completion in 1994/95, this work should result in a tested, user-friendly capability to relate short-term measurements at a candidate wind-turbine site to long-term wind climatology at a nearby weather or climatological station.

2.6.4 Gaussian and Heavy Gas Research

- C.S. Matthias

A dense gas plume model was developed, describing the successive processes of gravitational slumping, entrainment into a stable layer, and finally passive entrainment. An additional model was required to simulate two phase jet releases from pressurized tanks, prior to the application of the dense gas model. Model concentrations compared well with data from 7 experiments.

2.6.5 Automatic Recognition of Ice State

- B. Kerman

Two contracts were awarded: to Prof. S. Lovejoy of the Physics Department of McGill University to

conduct further analysis of the anisotropy of imagery: and to Prof M. Ostoja-Starzewski of the Department of Material Sciences and Mechanics at Michigan State University to develop a micro-mechanical model of an ice field as a basis for the project. Proposals for extended work will be made to the AES/CCRS ice groups, the Transportation Development Centre, the Search and Rescue Secretariat, and possibly several US agencies.

2.6.6 Global Meteorological Sulphur Transport Model
- A. Dastoor and J. Pudykiewicz

The pack ice covered Arctic ocean is practically free from sources of gaseous and particulate trace substances in the atmosphere. However, several measurement campaigns have provided evidence of a quite polluted Arctic in the winter and the spring. In the past, there has been some effort in coupling regional sulphur transport models to 3-D meteorological models but so far there has been no attempt to simulate the long-range transport of anthropogenic sulphur to the Arctic using a fully prognostic numerical global meteorological tracer transport model. The advantage of this model is that the physical processes in the atmosphere are dynamically linked together with the advection.

Clouds play an important role in the formation of sulphate and in the long-range transport of sulphur in the troposphere because of its dependence on the space-time scale of the precipitation events. So far, the incomplete description of clouds and precipitation has represented a major limitation to the modelling of wet chemical processes on a global scale. One of the most novel element in this study is a realistic representation of the interaction between clouds and chemical reactions. The model includes a sophisticated sub-grid scale convective and stratiform condensation scheme which includes cloud liquid water content as a predictive variable.

A global meteorological sulphur transport model was constructed using the Canadian global forecast model. The model includes the representation of multiple 3-D anthropogenic sources, positive definite semi-Lagrangian advection of sulphur species, and their chemical and physical interactions.

Parameterizations for the in-cloud oxidation of SO_2, the uptake of sulphate cloud condensation nuclei, and the in-cloud and sub-cloud scavenging of sulphur (SO_2 and SO_4) by precipitation were developed. Also the release of sulphate to the atmosphere from a dissipating cloud and from the evaporation of precipitation is parameterized. The turbulent boundary layer mixing of the sulphur species is performed using a scheme based on the calculation of the eddy diffusion coefficient specified by the time-dependent equation for turbulent kinetic energy and of a mixing length governed by a relaxation process. The model also calculates the wet and dry deposition fluxes of sulphate at the surface.

The global sulphur transport model described above is being used to examine the mechanism of sulphur transport to the Arctic. The short residence time of sulphur allows the model to establish the global sulphur distribution equilibrium in a relatively short integration. Using selected episodes, different meteorological conditions responsible for long-range sulphur transport to the Arctic can be examined. Different processes and source regions responsible for the Arctic air pollution are being identified and evaluated. Model simulations are being performed to produce the annual cycle of the Arctic air pollution of the sulphur species.

2.7 AIR QUALITY SERVICES

2.7.1 Modelling for Air Pollution Emergency Response
- S.M. Daggupaty and P. Cheung

The PC-Version of AQPAC (Air Quality Package of Programs) has been further modified with the following processes: (i) The source strength model now accounts for the amount of vapour in the vapour space of the non-flashing liquid containers. This was considered only for flashing liquid containers in earlier versions; (ii) Maximum pool radius for chemical pools is computed such that there exists a balance between the liquid leak flow rate and evaporative rate. This feature automatically checks the user-specified pool radius and will not allow it to exceed maximum pool radius, so that conservation of mass is obeyed; and (iii) evolution of either plume or puff and change of source strength with time and duration of evaporation and other processes are streamlined comprehensively for all applicable scenarios.

The PC-AQPAC users manual was completed. It describes system features, procedures and options along with explanation from chemical selection to graphical model output. This version 1.2, along with the manual, is now on sale and about 60 copies have been sold in Canada, including Environment Canada. Now PC-AQPAC version 1.2 is operational at all DOE regional weather centres.

As a validation exercise, PC-AQPAC was run for

several case studies of field experimental data collected by AECL during the tracer study (1979-1983) at Whiteshell Laboratories. This exercise is initiated by COG (Candu Operators Group) and managed by AECL, Chalk River. The results are being finalized.

2.7.2 Mesoscale Boundary Layer Forecast Model
- S.M. Daggupaty

A paper describing the three dimensional mesoscale boundary layer forecast model (BLFM) was accepted for publication and a second paper describing case studies using Pickering Meso-network data is being written.

P. Chueng is successfully accessing the required meteorological data for the mesoscale model studies. The code of the mesomodel is being modified so that it will be operational on the HP workstation. Time-dependent boundary values from the Regional Finite Model (RFM) will be used for real-time operational use. It is planned to modify and use the Urban Airshed Model for transport and dispersion of pollutants in combination with the mesoscale model for air pollution studies, particularly with reference to the Hamilton impact study.

2.7.3 RDMQ System
- W. Sukloff

The Research Data Management and Quality Control System (RDMQ) comprises of a set of computer programs for quality controlling and managing environmental measurement data. RDMQ was applied to two research programs within the Branch -- the Canadian Air and Precipitation Monitoring Network (CAPMoN) and the Air Toxics Research Program. In CAPMoN, RDMQ was applied to the precipitation sampling system and was validated against the existing set of quality control programs. It will be put in use in the spring of 1994. For the Air Toxics Program, the system was partially implemented for PCB and metals data. Data visualization and blank correction algorithms were programmed into the system to assist quality control and data finalization. Plans were made for applying the RDMQ Toxics system to the U.S. Great Lakes Toxics Program under funding from the United States Environmental Protection Agency.

2.7.4 Centre for Atmospheric Research Experiments
- F. Froude

The Centre for Atmospheric Research Experiments (CARE) is an inter-disciplinary research facility to collect data and support both short-term and long-term observational studies. The various programs involve air quality, biometeorology, climate measurements and associated standards, as well as instrument development and evaluation.

The Centre is operated by the Air Quality Research Branch who have responsibility for the facility and the measurement programs. Experiments are carried out by research groups of Environment Canada and others including universities and private organizations in cooperation with on-site staff. Projects are initiated by proponents contacting the CARE manager with a project request.

CARE is located in an agricultural area of rural Southern Ontario, approximately 15 kilometres southwest of Barrie and 6 kilometres west of Highway 27 near Cookstown, Ontario.

Table 1 is a list of projects that were active in 1993. A more detailed description of each project is available in the annual CARE report or elsewhere in this report under the appropriate program activity for Branch projects.

2.7.5 Air Quality Services
- M. Still

A Branch retreat was held in April 1993. In the context of the AES business plans, the evolving AES organizational structure and our shrinking resource expectation, the objectives of this retreat were to agree on where we want to be in 3-5 years, to annunciate the specific actions that will get us there, and to obtain commitment and accountability from individuals on behalf of the Branch to ensure the agreed actions are undertaken and completed successfully.

The meeting concluded that the vision of the Branch was that it was a research community advancing scientific knowledge on air quality for the well-being of Canadians. In line with this the Branch had a mission that through research, it would provide Canadians with scientific information and advice on air quality issues as a basis for informed decision-making. The Branch would achieve this mission by advancing the operational and developmental requirements of the AQRB mission, by improving our effectiveness, by enhancing our quality of science and by increasing efficiency. A list of possible actions to achieve these objectives was formulated for the Branch to implement.

NETWORKS

NAME	TYPE OF MEASUREMENT	SPONSOR
CAPMoN (Canadian Air & Precipitation Monitoring Network)	✡ Precipitation chemistry ✡ Air filter pack ✡ Ozone	✡ AES - ARQM
NDDN (National Dry Deposition Network)	✡ Air filter pack	✡ U.S. - EPA
Acid Aerosols & Health Effects	✡ Annular denuder (HEADS) ✡ Filter pack ✡ Dichotomous sampler	✡ AES - ARQP ✡ Health Canada ✡ EPS - Pollution Measurements Division
IADN (Integrated Atmospheric Deposition Network) - Egbert, Point Petre, Burnt Island - organics	✡ PCBs, PAHs, pesticides, trace metals ✡ Total organic carbon ✡ Total suspended particles ✡ Meteorological data ✡ Organics in precipitation	✡ AES - ARQP/CARE (GLWQA)
Climate Reference Station	✡ Precipitation amount ✡ Air & soil temperature ✡ Wind speed & direction ✡ Sunshine (Campbell Stokes) ✡ Global, reflect and net radiation	✡ DOE - Ontario Region
Visibility Monitoring - IMPROVE - Light scattering	✡ Aerosol filter pack (2.5 to 10 microns) ✡ Nephelometer	✡ U.S. - EPA ✡ U.S. - National Parks Service ✡ University of Guelph ✡ AES - ARQP
Solar Radiation	✡ Radiometer	✡ AES - ARQX

INSTRUMENT TESTING

NAME	TYPE OF MEASUREMENT	SPONSOR
Soil Thermistor	✡ Proof of performance test for operational use	✡ AES - AWPT
Temperature Shield & Humidity	✡ Evaluation of Stevenson Screen roof materials ✡ Evaluation of commercially-available temperature shields	✡ AES - AWPT
Rain Gauge	✡ FIMCO rain gauge; TE525M rain gauge; Nova Lynx rain gauge; F.M.Y. rain gauge	✡ Campbell-Scientific Canada
FTS Tipping Bucket Intercomparison	✡ Type B rain gauge; Fischer-Porter precipitation gauge; MSC tipping bucket; MSC copper rain gauge; Pit rain gauge	✡ AES - CCAD/D

TABLE 1: Projects at CARE

INTENSIVE FIELD STUDIES

NAME	TYPE OF MEASUREMENT	SPONSOR
Atrazine in Air	✡ PUF samples @ CARE & Pt. Petre ✡ PUF samples from aircraft	✡ Agriculture Canada ✡ AES - ARQP ✡ AES - CARE
Satellite-derived Water Temperature	✡ Radiosonde profile	✡ Mullard Space Science, University College, London, England ✡ AES - CCAD
Interferometer Testing	✡ Measurement of HCL and CH_4	✡ AES - ARQX
Visibility - Visibility/aerosol apportionment - aerosol measurements	✡ Scattering and absorption of light (20 nm to 20 μm) ✡ Particle growth from humidity ✡ Study of nucleation mode of particle behaviour and test of chromatography instrumentation	✡ AES - ARQP ✡ University of Hannover ✡ University of Hannover ✡ AES - ARQP
Fog Water	✡ Samples collected using in-house developed collector; Analyses at NWRI to determine level of organic contaminants	✡ AES - CARE ✡ AES - ARQP ✡ NWRI
Tropospheric Gases	✡ Optical measurements using downward-looking aerosol LIDAR, long-path light absorption spectrometer and tropospheric DIAL	✡ AES - ARQP
Aerosol Measurements Intercomparison	✡ Comparison of data collected by the following methods; IMPROVE, IADN, dichotomous sampler and impactors	✡ AES - ARQP ✡ University of Guelph
Sunshine Recorder Intercomparison	✡ Comparison of AES electronic sunshine recorder and Campbell-Stokes	✡ AES - CCID
Radio Spectrum Monitoring	✡ RF monitoring station computer-controlled by modem	✡ DOC
National Precipitation Evaluation Station	✡ WMO precipitation standards for comparison of historical and new measurement methods	✡ AES - CCRD
Bioclimate Monitoring	✡ Dial-in bulletin board of data from 3 electronic climate stations	✡ AES - CCAD/B
Autostation Comparison	✡ Climate data comparison from co-located climate and hydromet stations	✡ AES - CCRD
Climate Buffering Capacity of Forest	✡ Monitoring of climatic processes from a forest clearing through a closed forest canopy	✡ AES - CCAD/B

TABLE 1 (continued): Projects at CARE

2.8 BRANCH PUBLICATIONS

2.8.1 Journal Publications (1993/94)

Barrie, L.A., 1993: "Features of Polar Regions Relevant to Tropospheric Ozone Chemistry", In: Tropospheric Chemistry of Ozone in Polar Regions (eds.: H. Niki and K.H. Becker), Springer Verlag, p.3-24.

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Falconer, R.L., and **T.F. Bidleman** 1993: "Vapor Pressures and Predicted Particle/Gas Distributions of Polychlorinated Biphenyl Congeners as Functions of Temperature and Ortho-Chlorine Substitution", Atmos. Environ., 28, p.547-554.

Fast, H., C.T. McElroy, D.I. Wardle and J.M. Rosen 1993: "Wintertime Measurements of Stratospheric HNO_3 as part of the ISY Polar Ozone Project", Geophys. Res. Lett., 20, p.2547-2550.

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Glooschenko, W.A., N.T. Roulet, **L.A. Barrie**, H.I. Schiff and H.G. McAdie 1994: "The Northern Wetlands Study (NOWES): An Overview", J. Geophys. Res., 99D1, p.1423-1428.

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Hedley, K.J., P.B. Shepson, **L.A. Barrie**, **J.W. Bottenheim**, **D. MacTavish**, **K.G. Anlauf** and G.I. MacKay 1993: "An Evaluation of Integrating Techniques for Measuring Atmospheric Nitrogen Dioxide", Int. J. Environ. Anal. Chem., 54, p.167-181.

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McCormick, M.P., D.M. Winker, E.V. Browell, J. Coakley, C.S. Gardner, **R.M. Hoff**, G.S. Kent, S.H. Melfi, R.T. Menzies, C.M.R. Platt, D. Randall, J. Reagan and J. Theon 1993: "Scientific Objectives of the Lidar In-Space Technology Experiment", Bull. Amer. Meteorol. Soc., 74, p.205-214.

Muir, D.C.G., M.D. Segestro, P.M. Welbourn, **D. Toom**, S.J. Eisenreich, C.R. Macdonald and **D.M. Whelpdale** 1993: "Patterns of Accumulation of Airborne Organochlorine Contaminants in Lichens from the Upper Great Lakes Region of Ontario", Environ. Sci. Technol., 27, p.1201-1210.

Neumann, H.H., G. den Hartog, K.M. King and A.C. Chipanshi 1994: "Carbon Dioxide Fluxes Over a Raised Open Bog at the Kinosheo Lake Tower Site During the Northern Wetlands Study (NOWES)", J. Geophys. Res., 99D1, p.1529-1538.

Ngabe, B., R.L. Falconer and **T.F. Bidleman** 1993: "Base Hydrolysis of Alpha- and Gamma-Hexachlorocyclohexanes", Environ. Sci. Technol., 27, p.1930-1933.

O'Neill, N.T., A. Royer, P. Coté and **B. McArthur** 1993: "Relations Between Optically Derived Aerosol Parameters, Humidity and Air Quality Data in an Urban Atmosphere", J. Appl. Meteorol., 32(9), p.1484-1498.

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Walmsley, J.L., 1993: "The Transatlantic Fate of Tropical Storms", Weather, 48, p.350-359.

Whelpdale, D.M., (ed.) 1993: " EMEP Workshop on Combined Analysis of Measurements and Model Results with Special Emphasis on NOx/VOC/Oxidants", Atmos. Environ., 27A, p.805-1049.

2.8.2 Other Publications (1993/94)

Bidleman, T.F., and D.C.G. Muir (Guest editors) 1993: "The Analytical and Environmental Chemistry of Toxaphene, Proceedings of the Toxaphene Workshop", Chemosphere, 27, p.1825-2094.

Brauer, M., **J.R. Brook** and M. Raizenne 1993: "A Pilot Study to Assess Personal Exposures to Ozone in the Fraser Valley of British Columbia", In: Proc. EPA/AWMA Symposium on the Measurement of Toxic and Related Air Pollutants, Durham, NC, May 1993.

Brook, J.F., 1993: "The Canadian Acid Aerosol Measurement Program 1992-93", Internal Report, Air Quality Research Branch, Fall 1993.

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Chakrabarti, C.L., J. Cheng, Y. Lu, M.H. Back and **W.H. Schroeder** 1993: "Kinetic Studies of Metal Ion Speciation in the Environment", In: Proc. Int. Conf. on Heavy Metals in the Environment (eds.: R.J. Allan and J.O. Nriagu), CEP Consult.Ltd., Edinburgh, U.K., 2, p.227-230.

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Cunningham, J.C., K.W. Brown, N.J. Payne, G.G. Grant, R.A. Fleming, A. Robinson, R.D. Curry, D. Langevin, T. Burns and **R.E. Mickle** 1993: "Aerial Spray Efficacy Trials with a Cyanamid Formulation of Gypsy Moth NPV and with FORAY 48B in 1993", Final report to American Cyanamid Co.

Daggupaty, S.M., **R.S. Tangirala** and H.Sahota 1993: "A Mesoscale Boundary-Layer Forecast Model for Air Pollution Emergencies", Hazards '93, 97, 5th Int. Conf. Natural and Manmade Hazards, Qingdao, China August 29 - September 3, 1993.

Farrell, T.C., B.L. Beattie and **R.E. Mickle** 1993: "Comparison of Pesticide Spray Deposition Model Results with Operational Measurements", Regional report MAES 2-93.

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MOEE-**AES** 1994: "Interlaboratory Study 92-4: Trace Metal Standard Solutions in Support of the Integrated Atmospheric Deposition Network", ARD Report 93-14, January 1994.

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Walmsley, J.L., and S.R. Karpik 1993: "MSFD-PC: A Computer Model Package for Wind Flow and Turbulence Estimates in Complex Terrain:, Proc. 9th Annual CanWEA Conf., Pincher Creek, Alberta, September 20-22, 1993, p.309-316.

Wardle, D.I., **J.B. Kerr** and **C.T. McElroy** 1993: "Operational Ozone and Spectral UV-B Monitoring in Canada", In: Proc. 13th UOEH Int. Symposium on UV-B Exposure Impacts on Human Health and Ecosystems, Kitakyushu, Japan, October 1993, 22pp.

AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

1993/94

STAFF INFORMATION

AIR QUALITY RESEARCH BRANCH

SCIENTIFIC EXPERTISE

Anlauf, K.G.	Atmospheric chemistry; pollution measurement instruments and methods
Barrie, L.A.	Atmospheric chemistry; Arctic haze; atmospheric removal processes - wet and dry
Bottenheim, J.W.	Atmospheric chemistry; measurements; modelling; nitrogen chemistry
Daggupaty, S.M.	Air quality modelling; transport and dispersion in boundary layer; mesoscale meteorology
den Hartog, G.	Dry deposition; eddy fluxes; micrometeorology
Higuchi, K.	Global biochemical cycles and climate research
Hoff, R.M.	Lidar and DIAL; remote sensing; toxic chemicals; Arctic haze
Hopper, F.	Naturally emitted compounds & their impact on climate
Kerman, B.R.	Boundary layer turbulence; acoustic sounding; underwater sound; air-sea interactions; gas/particle exchanges
Kerr, J.B.	Ozone depletion; ozone trends; UV radiation
Lane, D.A.	Photochemistry of PAH; chemical and physical properties of PAC; mass spectrometry; instrument and methods development
Lo, A.K.	Meteorological parameters and flux profile relations in transport and deposition of air pollutants
Matthias, C.S.	Short range dispersion modelling
McArthur, L.J.B.	Solar radiation; UV radiation; measurement techniques
McElroy, C.T.	Remote sensing of atmospheric constituents and pollutants; UV radiation
Mickle, R.E.	Detailed measurements of planetary layer using tethersondes; drift and deposition of pesticides from aerial application
Neumann, H.H.	Dry deposition measurement; micrometeorology; air pollution
Padro, J.	Boundary layer; dry deposition; climate
Schroeder, W.H.	Atmospheric chemistry; toxic chemicals
Trivett, N.B.A.	Microclimatology; energy balance; RAGS monitoring
Voldner, E.C.	Acid and toxic chemical modelling; exchange processes; data analysis; model evaluation
Walmsley, J.L.	Computer modelling of wind flow in complex terrain
Wardle, D.I.	Ozone science; UV radiation
Whelpdale, D.M.	Acid rain; chemical meteorology; atmospheric chemistry
Wiebe, H.A.	Atmospheric chemistry; environmental chemical measurements; acid precipitation in eastern Canada; network operations

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		TONNA, C.	4470	4S103
		ALLAN, T.	4278	4S103/4
		BIASI, D.	4850	4S103/4
ARQS	**AIR QUALITY SERVICES LIAISON OFFICE**			
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	Secretary	MATHIS, E.	4849	4S607
		ARNOLD, J.	4855	4S601
		CHEUNG, P.	4579	3S509B
		DAGGUPATY, S.M.	4451	4S402
		DASTOOR, A.	(514) 421-4766	Dorval
		DERCO, S.	4856	4S602
		GONG, W.	4883	3S508
		LI, A.(Y.F.)	4892	3S507
		LO, A.	4854	3S501
		MATTHIAS, C.	4448	4S409
		OIKAWA, K.	4871	4S403
		OLSON, M.	4870	4S109
		PABLA, B.	4670	4S626
		PADRO, J.	4857	4S605
		PUDYKIEWICZ, J.	(514) 421-4744	Dorval
		QI, Y.	4659	3S505
		SIROIS, A.	(514) 421-4674	Dorval
		SOBKOWICZ, C.	(514) 421-4759	Dorval
		SUMMERS, P.	4204	3S510A
		VOLDNER, E.	4467	4S313
		WALMSLEY, J.	4861	4S608
		WENG, W.	5734	3S504
		WHELPDALE, D.	4869	4S108
		ZHANG, L.	4236	3S504

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		ALEXANDROU, N.P.	4600	4S124
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