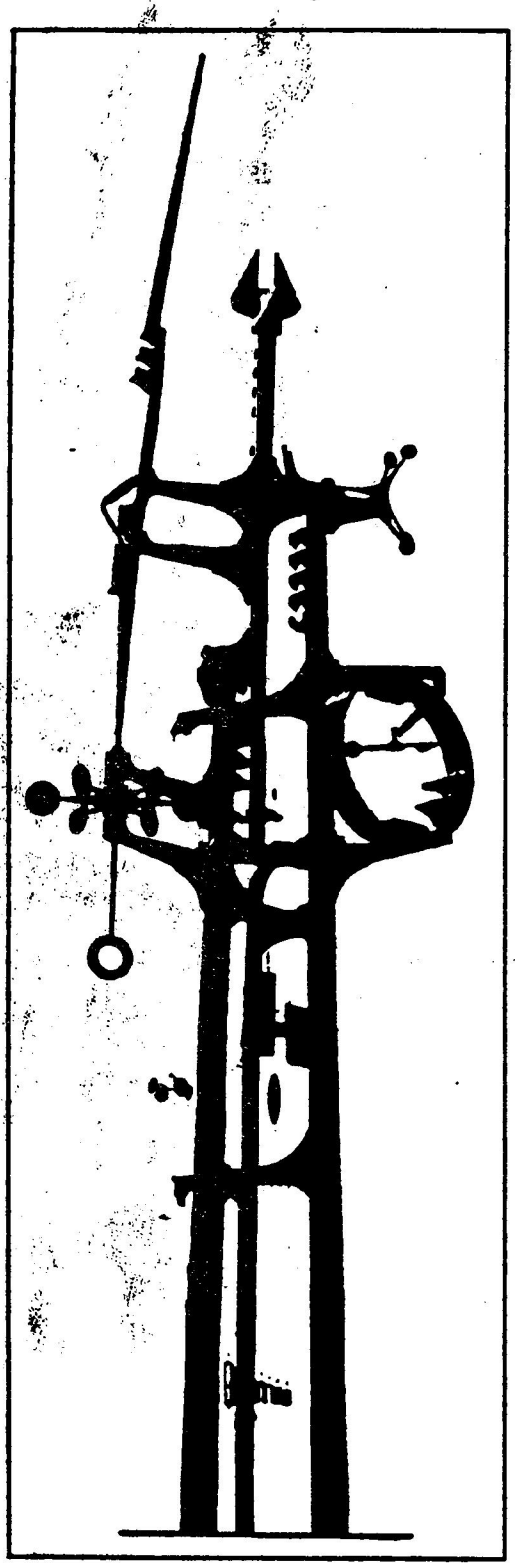

AIR QUALITY

RESEARCH BRANCH

ANNUAL REPORT

1992-93

Environment Canada | Environnement Canada
Atmospheric Environment Service | Service de l'environnement atmosphérique

AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

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Compiled by

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June 1993

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

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AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

1992/93

1.0 FOREWORD

1.1 Awards

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. A plaque indicating the past winners is on display in the AES library at 4905 Dufferin Street. The 1992 winners were:

Sam Daggupaty for his dedicated years to the development of a unique package of dispersion models (AQPAC) for use in environmental emergency response.

Hans Fast for his superb organization of the field experimental campaigns of the Experimental Studies Division, especially those associated with CANOZE (Canadian Ozone Experiment).

Al Gallant for his planning of the Polar Sunrise Experiment and for his organization of laboratory facilities at York University in support of the CCME NOx/VOC Management Plan.

Syed Iqbal for his effective and elegant solution to reduce the loss of integrity of CAPMoN precipitation samples through leaks in the sample bag.

David Wardle for his highly responsible way of carrying out the duties of Division Chief during a period of great stress due to public concern for the ozone layer.

1.2 Overview

A 32-page brochure on the research activities of the Branch has been produced. It includes a list of contacts for specific research projects.

Throughout the year the Branch provided continuous scientific support for government policy initiatives relating to air pollution issues. In addition, on the international front, staff were involved with international activities, including the Canada/U.S. Accord on Air Quality, the Arctic Environmental Protection Strategy (eight circumpolar countries), the Economic Commission for Europe (ECE), Transboundary Air Pollution Convention, the Montreal Protocol, the Intergovernmental Panel on Climate Change, and numerous bi-lateral cooperative projects.

The total budget (including salaries) for the year was $18,699,000 with a staff complement of 125 and, in addition, 45 part-time students.

2.0 BRANCH PROGRAM

2.1 ACID DEPOSITION

2.1.1 Program Management
- K. Puckett

Modelling and monitoring information on current and projected acid deposition was provided as preparatory material for the Canadian position on the ECE SO_2 Protocol.

In preparation for the next Progress Report of the Canada/U.S. Agreement on Air Quality, Federal/Provincial acid rain monitoring and modelling programs have been reviewed. Draft outlines for the next report have been agreed upon with the U.S. and writing responsibilities decided for the Canadian contribution to the report. The U.S./Canada workplan for producing the report will be reviewed in May 1993.

AES is a member of National and Regional Working Groups on PSD (Prevent Significant Deterioration)/Visibility put in place to define the Canadian response to the PSD/Visibility provisions in the U.S./Canada Air Quality Agreement. AES was a co-sponsor of the Workshop on PSD/Visibility held in Harrison Springs, B.C.

The role of nitrogen deposition in the acidification process is currently being addressed. As part of the assessment, modelled and measured estimates of nitrogen deposition were provided to National Water Research Institute.

The mid-term review was held in September. As before, the meeting serves to review progress against project objectives and also to inform others on the scope and level of activity of the program.

2.1.2 Lagrangian Model
- M. Olson, K. Oikawa and B. Pabla

The inter-active trajectory model and data archive were converted to a UNIX-based operating system. The trajectory model was expanded to a hemispheric grid and the resolution was increased to about 200 km.

The sulphur model was run for the 1985 base case, and for the U.S. and Canada sulphur emission control program future scenarios to produce wet and dry SO_4 deposition maps for eastern North America. The nitrogen model was also rerun for 1985 to produce dry and wet NO_3 deposition maps for eastern North America.

The ALOM (AES Lagrangian Oxidant Model) model was used to test several chemical reaction schemes, especially for terpene and isoprene. Comparisons with 1988 EMEFS (Eulerian Model Evaluation Field Study) data showed that surface concentrations of species such as H_2O_2 and PAN were overpredicted, isoprene was underpredicted, and ozone and CH_2O were predicted reasonably well. These results were consistent with the box model/layer average structure of the model.

The sulphur model was run in collaboration with the AES Western Region and a sulphur budget was produced for Alberta for 1985. In cooperation with the AES Ontario Region, an intercomparison between the Eulerian model (ADOM - Acid Deposition & Oxidant Model), the Lagrangian sulphur model and the measured data was done for the 1983 PERD (Panel on Energy Research & Development) episode.

2.1.3 ADOM Evaluation
- K. Puckett, A. Macdonald, S. Li, J. Padro and H. Wiebe

An external peer review of the ADOM (Acid Deposition and Oxidants Model) evaluation was generally favourable. The model was judged to be acceptable for use in estimating the relative change in sulphur and nitrogen deposition arising from different emission change scenarios. At year end, the major inputs for the model (meteorological and emission fields) were ready and another major task, the conversion of the model code to the new UNIX operating system, was almost complete so that new simulations can be undertaken. Surface measurements and measurements aloft have been prepared for comparison with the new model simulation periods of November - December 1988 and March - May 1990.

Dry deposition modelling of O_3, SO_2 and particulate matter, and testing of the ADOM module for O_3, SO_2 and particulate matter has continued. The 1991 California Ozone Deposition Experiment (CODE) provided data for modelling dry deposition over a vineyard and the results are now being prepared for publication. The influence on dry deposition of a wet Camp Borden forest was studied. O_3 and SO_2 are affected differently and depend on whether the wetness is caused by rain or dew: dew is sometimes confused with guttation. A paper was published on the sensitivity of the ADOM Eulerian model to changes in the dry deposition parameterization. Although large changes were seen in the dry deposition parameterizations, ADOM continued to underpredict the surface concentrations of O_3 and SO_2. There is some other error in ADOM that needs to be explored. A paper was published on the possibility of using the variance-flux equations to obtain fluxes from scalar parameters. They seem to serve well for temperature and water vapour but not so well for O_3, SO_2 and CO_2.

Evaluation of ADOM using aircraft data for the summer 1988 period was continued. Results were presented at the Spring AGU meeting in May 1992. A further analysis on the EMEFS 1988 data was carried out based on the technique of absolute principle component analysis. The same technique was applied to the ADOM output for the ground level. The results were presented at the 1992 AGU fall meeting.

2.1.4 Dry Deposition Estimates
- J. Brook

Monthly and annual dry deposition velocities of SO_2, HNO_3 and SO_4, estimated using the land-use model of Voldner, Sirois and Barrie, and the U.S. National Dry Deposition Network (NDDN), were compared at 6 sites. The differences between these models were generally within the range of uncertainty associated with inferential estimates. However, some systematic differences which varied with pollutant and land-use type were observed. A more rigorous comparison of these models - along with J. Padro's modified ADOM, with a multi-layer model being adopted by the NDDN and with a model combining the strong points of each model - is underway. These models will be contrasted with the Borden and San Joaquin measurements. From this comparison, the best available inferential model for making routine estimates of dry deposition using existing and future air concentration data will be selected.

2.1.5 Eulerian Model Evaluation Field Study
- K. Anlauf, S. Li and R. Vet

Further analyses have been completed on the Spring 1990 EMEFS (Eulerian Model Evaluation Field Study) Intensive. Several papers have been written that deal with partitioning of nitrogen oxides and correlations of nitrogen oxides with ozone at several sites in northeastern America including Egbert and Dorset, Ontario. Several other papers on hydrogen peroxide and peroxylnitrate/ozone correlations are in progress.

A revised paper on modelling the nighttime nitrogen chemistry for a period during the Summer 1988 EMEFS Intensive has been accepted for publication. The revision came after substantial numbers of sensitivity tests on the input parameters for the time-dependent box model which simulates the nighttime nitrogen chemistry, especially that related to the formation of particle nitrate. The sensitivity results re-enforce the conclusion reached in the earlier version of the paper.

The data base of U.S.-Canada surface measurements was finalized and sequestered for model evaluation. A draft report describing the quality of the measurement data was produced and sent for external peer review. The report is called the EMEFS Quality Assurance Synthesis Report.

2.1.6 Acid Aerosol Measurements
- J. Brook, A. Wiebe and S. Woodhouse

Seven monitoring sites in the Canadian Acid Aerosol Monitoring Program (CAAMP), extending east from Windsor, were brought into operation in June. The majority of them have been running continuously, providing data on 24 hour (0800-0800 EST) concentrations of p-H^+, p-SO_4, p-NO_3, p-NH_4, HNO_3, SO_2, PM2.5 and PM10. NH_3 concentrations are being determined at four of the sites. The first formal data report will be complete in April 1993. Laboratory, field and data management techniques are currently being refined to increase quality and speed of data reporting.

Preliminary CAAMP measurements of p-H^+ and p-SO_4 from Kejimkujik and Sutton show that these 1992 measurements agree with the estimates, which indicate that the H^+ to SO_4 ratio is greater at Kejimkujik, and are consistent with the observation that there is a greater incidence of respiratory problems in the Maritime region. The Summer of 1992 was unusually "clean", but during the eastern North America episode that occurred on August 23-25, 1992, 11 sites were collecting data. The spatial and temporal variation in H^+, SO_4 and NH_4 observed during this period is being examined more closely.

2.1.7 Visibility Research
- R. Hoff and L. Guise-Bagley

As part of the 1990 Canada/U.S. Accord on Air Quality, Canada is tasked with providing, by 1995, controls to prevent significant deterioration (PSD) of visibility from sources of transboundary air pollution comparable to those which exist in the U.S. Clean Air Act. To determine the impact of this mandate, considerable effort has been expended to understand the rules and procedures used within the U.S. for PSD control and to evaluate the usefulness of the U.S. procedures in the Canadian context.

In order to provide scientific advice and information, research has been started this year to attack the visibility issue on three fronts: development of the measurement technology by which accurate air quality related visibility measurements can be made; assessment of existing airport visibility data quality and extension to ranges relevant to air quality needs; and development of visibility models which can use the measurement data to predict visibility reduction in a prognostic sense.

In the first regard, nephelometry and transmissometry has been investigated at CARE (Egbert, Ontario). Using systems which are common to the U.S. National Parks Service IMPROVE program, we have evaluated two instruments which measure visibility to an accuracy of 0.5 Rayleigh or better (one Rayleigh is the amount of attenuation of the atmosphere with no particles present in air). These instruments are being tested against particle sizing probes, black carbon integrating plate samplers and lidar to determine whether sufficient understanding exists to apportion the visibility reduction of the atmosphere to the individual aerosol species in air.

For the second thrust, AES contracted to develop a statistical technique by which censored visibility data observed at hourly weather stations could be uncensored. These data are only reported to 25 km or less in Canada and many visibility observations are significantly higher than this maximum range. In a paper, airport visibility observations have been uncensored by extending the cumulative frequency distributions obtained from the uncensored data into the censored data region and estimates of median visibilities obtained. The results correct some obvious

discrepencies which were reported in the U.S. NAPAP visibility document.

The final thrust of developing models to predict visibility reduction is only beginning.

2.1.8 CAPMoN Operations

- S. McNair, W. Kobelka, A. Gaudenzi, S. Iqbal, M. Underwood, S. Beauchamp (MAES) and W. Belzer (PAES)

Measurements continued at 24 precipitation and 12 air monitoring sites in the Canadian Air and Precipitation Monitoring Network (CAPMoN). The filter pack system was upgraded by substituting flow controllers for flow meters and by installing on-site telemetry systems at 9 of the 12 air monitoring sites. AES Regional Inspection staff assumed full responsibility for the routine maintenance and calibration of the precipitation and filter pack measurements at all sites.

2.1.9 CAPMoN National Laboratory

- D. MacTavish, T. Knott, R. Braga, R. Kessler, N. Lance, K. So and L. Beauregard

The chemical analyses of CAPMoN precipitation samples and air filters were maintained in spite of the turmoil experienced through the relocation of the laboratory.

The decision by the National Laboratory for Environmental Testing (NLET), National Water Research Institute, not to continue its commitment to the analysis of CAPMoN precipitation samples necessitated the closure of the laboratory at the Canada Centre for Inland Waters in Burlington, Ontario. This has resulted in the merger of CAPMoN's air filter and precipitation sample analysis laboratories in a leased facility at York University. The NLET supervised laboratory was run in parallel for comparison purposes from December 1992 to March 1993. Although detailed analysis of these data has not been completed, a preliminary comparison did not show any significant biases.

The initial focus of the new laboratory has been the training of new staff, and the development and implementation of new and more efficient methods for the analysis of precipitation. Routine analysis of precipitation with a 10-day turn-around of data was attained by February 1993. Air filter analysis is expected to be back on schedule by June 1993.

The analysis of CAPMoN and dichotomous sampler samples from Esther, Alberta, in support of a project designed to provide information on the suitability of using open-face filter packs in a dusty environment has been completed. Indications are that more information is needed for the period from May to October and sampling will be re-started in April 1993.

2.1.10 CAPMoN Quality Assurance & Data Management

- R. Vet, S. Ahmed, M. Shaw and B. Sukloff

CAPMoN precipitation data were quality controlled to the end of 1992. All historical filter pack data were blank-corrected and prepared for final quality control to the middle of 1992. Ozone data were quality controlled to the end of 1992 with final quality assurance to the end of 1991.

The analysis and quality control of the CAPMoN ozone data progressed from the use of cassette tapes to telemetry data. The telemetry system improved the timely identification of problems and the corrective action and data turn-around time.

Data management was improved and speeded up through the development of a computer program for blank-correcting filter pack data. For precipitation chemistry data, a version of the CAPMoN Statistical Analysis and Reporting (CAPSTAR) software package was developed and tested for final use in 1993. This package will be used to distribute raw and statistical data to users.

2.1.11 NAtChem Data Base

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

NAtChem (National Atmospheric Chemistry Data Base) activity focused on prepublication work for the report "NAtChem 10 Year (1980-1989) Annual Report" and a site description document, "NAtChem Precipitation Sites". The former includes all historical wet deposition statistics for each site. The latter includes all available site and network information for every site. A draft of the 10-year report for the CAPMoN, APIOS-C, APIOS-D and NB networks was produced. A draft of the site document for each network was distributed to the network managers for review and the Site Information System Databases were updated. The site document includes point and area emission information around each site and a provincial map showing the location of the site. A "NAtChem Production Summary Report" explaining the NAtChem Databases and its products has been presented in conferences and distributed to the users in Canada, the U.S. and several Asian countries.

In this year there were 69 data and analysis requests. The major requests were: an

optimization analysis of the APIOS network; analyses for the selection of new CAPMoN sites in New Brunswick and Quebec using the NAtChem emission source identification routine; analysis of New Brunswick deposition data to estimate the amount of acid deposition due to U.S. emissions; and analysis of Newfoundland weekly sample data quality by comparing with CAPMoN daily sample data at the Bay d'Espoir collocated site.

A PC-based interpolation and mapping software system was initiated. This is a software system for personal computers to analyze and display air pollution, climate and emission inventory data. A commercial package is being investigated for the primary contouring software, which will then be further developed to meet NAtChem needs. This new contouring system will be available in September 1993.

A NAtChem and U.S. NADP/NTN data exchange agreement was signed in 1992 and NAtChem data were sent to the U.S. NAtChem also received data from NADP/NTN up to June 1992.

2.1.12 CAPMoN Assessment

- D. Whelpdale, J. Brook, A. Sirois and C. Blanchard

The objective has been to assess the suitability of CAPMoN to detect changes in deposition expected to result from sulphur emission controls in North America. CAPMoN is suitable for the detection of long-term temporal changes in precipitation chemistry in parts of eastern Canada, but has insufficient stations to delineate geographical patterns of deposition or to track the evolution of these patterns as emissions are reduced. Station density is too low in the northern portion of eastern Canada (north of 47°N) to permit reliable delineation of the deposition fields there.

There are CAPMoN stations located in current "hot spots" in northwestern and southwestern Ontario and in southern Quebec; these hot spots will persist at least until 2001, as emissions are reduced. However, there are no CAPMoN stations in hot spots in southeastern Ontario or in New Brunswick. The 20 kg/ha/y contour will recede most rapidly southward from the Lake Abitibi region. Four CAPMoN stations in southern Ontario are reasonably well placed to follow the east-west movement of the contour, and should be retained. However, large portions of central Ontario and western Quebec do not have CAPMoN stations to monitor the southward movement.

In Region 1, i.e., the area where deposition currently exceeds 20 kg/ha/y, the seven CAPMoN stations are sufficient to detect temporal trends by 1997, the planned end of Phase I U.S. reductions, with a 90% probability. Quantification of these trends in Region 1 would require an additional six or seven years. Detection of a temporal trend outside this region using only CAPMoN stations would require twelve or more years (western area) and seven or more years (eastern area). However, quantification of this trend would not be possible. In all cases, both detection and quantification can be improved if provincial stations are used.

2.1.13 North Atlantic Flux Study

- D. Whelpdale and J. Galloway

The objective is to quantify the fluxes into and out of the atmosphere of the North Atlantic Ocean. It is of interest to examine the degree of anthropogenic perturbation of the natural biogeochemical cycles of sulphur and nitrogen over the North Atlantic, and, from a more practical point of view, to examine the fluxes from North America to Europe, and fluxes into the Arctic. Wet and dry deposition represent the largest flux terms (e.g., > 80% of outflows), but they are also the most uncertain. Detailed examination of deposition has shown qualitative agreement with modelled fields, but also some large discrepancies off the west coast of Europe and the east coast of South and Central America. The paucity of deposition measurements over the ocean is main source of uncertainty in the atmospheric budgets for the region. This analysis is serving as a framework for field expeditions and model studies.

2.2 NOx/VOC MANAGEMENT PLAN

2.2.1 Program Management

- S. McNair and M. Phillips

Research was carried out in the areas of monitoring, modelling and vegetative effects by the various Working Groups of the NOx/VOC Science Program. Work focussed on: testing measurement methods for low NOx concentrations; analysing ozone data for various parts of Canada; developing models for the Windsor-Quebec Corridor, the South Atlantic Region and the Lower Fraser Valley; and analysing ozone effects on crops (by contract to the Alberta Research Council). Detailed planning and preparation for the Pacific '93 Field Study (to be carried out in the summer of 1993) was undertaken. The entire NOx/VOC Science Program underwent an extensive peer review in March 1993.

2.2.2 CAPMoN Ozone Measurements

- S. McNair, W. Kobelka, A. Gaudenzi, S. Iqbal, M. Underwood, S. Beauchamp (MAES) and W. Belzer (PAES)

Ozone measurements continued in the Canadian Air and Precipitation Monitoring Network (CAPMoN) at 7 of the 12 air monitoring stations. Data capture was increased markedly by replacing the monitoring instruments with a more reliable type, and by implementing a data and quality control telemetry package at most sites. The data to the end of 1991 were fully quality assured and submitted to the NAPS data base.

2.2.3 Ozone Measurements

- K. Anlauf and R. Schemenauer

Ozone has been measured continuously at the CHEF and Fraserdale sites. Data analysis of the first 6 months of 1992 CHEF ozone data has been completed and is being used by Quebec Region to correlate with Be_7 measurements made at the site. All other data are abstracted and analyzed on a yearly batch basis.

2.2.4 Dinitrogen Pentoxide Measurements

- S. Li

A computer-controlled, real-time continuous measurement system for dinitrogen pentoxide (N_2O_5) (easily modified for HNO_3 and particle nitrate) has been developed. The system is now being tested to determine its detection limit and its field-worthiness. Preliminary results show detection limit of about 100 ppt or better. Further improvements may improve the detection limit to the order of 10 ppt. This appears to be the first effort to measure N_2O_5 in the troposphere, and will be the first system capable of real-time continuous measurements of particle nitrate.

2.2.5 Nighttime Chemistry and Deposition

- A. Wiebe, K. Anlauf, S. Li, R. Mickle, G. den Hartog, R. Staebler and R. Hoff

On four nights during August 1992, measurements to investigate the physical chemistry of atmospheric gas-particle interactions were made at CARE (Egbert, Ontario). Measurements included the chemical precursors (NO, NO_2, O_3), the reactive intermediates (NO_3, N_2O_5) and the products (particle-NO_3, HNO_3 and HONO) which form through the gas-particle interactions. Profiles of NO_2 and O_3 were obtained by means of tethersondes which were used to raise and lower manifold tubing within the stable nocturnal layer. Winds, temperatures, relative humidities and heights were also measured by instrumentation attached to the tethersondes. The number and size distributions of atmospheric particles, as well as the chemical composition of various size ranges, were also measured.

During three of the four nights when measurements were made, large concentrations of O_3 and NO_2 were observed resulting in the formation of gaseous nitric acid and particle nitrate. Concentrations of O_3 were found to increase with height within the nocturnal layer suggesting deposition losses at the ground, whereas NO_2 concentrations were more uniform within the layer.

The data are currently being analyzed to determine the mass accommodation coefficient for N_2O_5 and atmospheric particles, and the heterogeneous reactions between the gas phase species and particles.

2.2.6 Hydrocarbon Emissions

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

Information on the distribution and magnitude of hydrocarbon emissions from deciduous and coniferous tree species is essential to understanding the contribution of naturally emitted hydrocarbons to the cycle of tropospheric ozone. The contribution of hydrocarbons emitted by Canadian forests to tropospheric ozone is unknown.

A project has been initiated to measure fluxes of hydrocarbons from deciduous (Borden) forests and to model hydrocarbon emissions at the plant canopy level. Measurements are also planned for coniferous trees as part of the BOREAS (Boreal Ecosystem-Atmosphere Study) experiments during 1994.

Hydrocarbons emitted by foliage (leaf and branch levels) will be measured using a combination of environment-controlled chamber systems and gas chromatography. The equipment is being tested with tree seedlings growing in a greenhouse. Field measurements of hydrocarbon emissions are planned for May and August 1993. Other measurements such as forest microclimate, forest leaf area and photosynthetically active radiation will be taken as well. Canopy models used to estimate biogenic hydrocarbon emission inventories are being examined using the Borden forest as a reference site. Hydrocarbon and microclimate measurements at Borden will assist in evaluating the usefulness of current models.

2.2.7 Optical Measurements

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

This project to measure optically aerosols and gases has three active thrusts supporting the objectives of the CCME NO_x/VOC Management Plan, plus a planning role for a space shuttle experiment.

The first thrust is the development of an airborne downward-looking lidar for use in boundary layer monitoring. This system has been developed and tested in an upward looking mode in the AES Lidar mobile laboratory. Using a Neodymium YAG laser operating at 1064 nm, the upward looking system was tested during the Nighttime Chemistry and Deposition experiments (see 2.2.5). The system operated for a two-week period, running 16-20 hours per day with less than a 5% loss in signal power over that period. Clearly, this system will be reliable for aircraft operation.

The design of the system within the AES mobile laboratory is identical (except that the telescope was configured in its upward looking configuration) to that which will be operated on the IAR Convair 580. The system will be used for the first time in Pacific '93 and later in the next fiscal year in the LITE (Laser In-Space Technology Experiment) validation program. In the meantime, the scanning facility on the ground mobile system will be refitted and tested for use for future use in the ARAL (AES Rapid Acquisition Lidar) budworm spraying application. In cooperation with the Canadian Climate Centre, experiments on the scanning system are being conducted to determine if the ARAL system has the sensitivity to detect pollen transport.

The second thrust is the redesign of the AES tropospheric ozone DIAL (Differential Absorption Lidar) system. This system is being redesigned to reach 15 km altitude using two Raman shifting cells to generate the ultraviolet wavelengths needed to measure ozone. The Raman efficiency tests brought some surprises in that higher order Raman scattering occurred in the designed cells and some loss in overall efficiency results. Nevertheless, the current Raman efficiencies of greater than 20% conversion from the 266 nm pump to the Raman line provides a factor of ten improvement in output power over the older dye laser pumped DIAL system.

The final thrust is the development of a Differential Optical Absorption Spectrometer to measure trace nitrogen species at low concentrations over long optical paths. During the Nighttime Chemistry and Deposition experiment, the system detected NO_2 at concentrations of 2.5 and 12 ppb in air over two nights of the study and it is believed that the ultimate sensitivity on those nights was about 0.2-0.5 ppb. Tests to detect HONO in air were not successful, perhaps because the HONO concentration was low and there were low signal levels in nighttime fog formation. Design changes to the optical input to the spectrometer are now being made which should allow a factor of 5-10 improvement in the instrument signal to noise.

Also covered under this project is the planning work for LITE; a lidar to be flown on the space shuttle in March 1994. The LITE instrument was tested at the Langley Research Centre in Hampton, VA, and, during the first night of testing, the LITE lidar profiled the atmosphere up to 60 km altitude. This impressive lidar system is on schedule for the 1994 launch. A validation experiment using the AES downward looking lidar under the shuttle flight track, and aerosol and cloud physics instrumentation on the Convair 580 is also in the planning stage. The experiment plan for this validation phase is to study coastal marine stratus, urban studies, and desert reflectance measurements in and off southern California.

2.2.8 San Joaquin Valley Air Quality Study (SQVAQS)

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

This was a collaborative field study in 1991 with the California Air Resources Board with the aim of measuring and parameterizing the dry deposition velocity of ozone for a variety of surface types in the San Joaquin Valley in California. Data abstraction and quality control have been completed. A final data and experiment report, including an error analysis, was submitted to the California Air Resources Board. The project has provided an extensive data set that is being used for testing deposition models.

2.2.9 NOx/VOC Modelling

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

Modelling activity was started for the Windsor/Quebec Corridor and for the Southern Atlantic Region under the NOx/VOC Management Plan. A working group was formed and an evaluation workshop was held in November 1992. An evaluation report was prepared and contracts have been let for model evaluation projects. The group plans to examine ozone episodes by running four oxidant models: ROM (U.S.E.P.A model run by Ontario Hydro/AES);

Gesima/ADOM (run by OME); ALOM; and RFE (Regional Finite Element model)/ADOM (run by AES).

2.2.10 Data Analysis

- J. Fuentes and P. Summers

A detailed statistical study has been completed to characterize the behaviour of ozone concentrations at all Canadian monitoring sites with data archived in the national data base. A 1-page summary has been prepared for each site with 11 charts showing such items as the daily and seasonal cycles, long-term trends, frequency of episodes and frequency of exceedances above certain thresholds. In addition, the large scale patterns of two long-lasting episodes in eastern North America in the summer of 1988 have been mapped to show the generation and motion. These analyses are being formulated to provide input to other projects in the NOx/VOC Science Program, especially the vegetation and health effects studies.

2.3 AIR TOXICS

2.3.1 Introduction

The atmospheric transport of air toxics is increasingly recognized as an important mechanism by which persistent toxic chemicals enter the ecosystem. The AES Air Toxics program had three major components in 1992/93:

- the Great Lakes program;
- the Arctic program; and
- the National program.

1992/93 was the fourth year of five years of Great Lakes Action Plan funding. While many things, such as the Canada/Ontario Agreement, were in a state of change, the AES program stabilized considerably with meeting our binational commitments under the Great Lakes Water Quality Agreement as the major objective.

A Binational Workshop on quality assurance and control was held at Research Triangle Park in North Carolina in November. Progress was made toward establishing a Program Plan for the entire Integrated Atmospheric Deposition Network.

The Arctic program had three major components, the establishment of sources of toxic chemicals, the modelling of transport through the atmosphere, and the measurement of selected organochlorines and polycyclic aromatic hydrocarbons in Arctic air. Substantial support was available for the monitoring, some support was available for the establishment of sources but little was available for the modelling work.

Progress on the National program occurred in two areas. The Quebec Region successfully operated an air toxics sampling site at Villeroy and a number of Priority Substance List Assessments were reviewed in support of C&P.

In 1992/93 a mid-term review of the toxic program was held in November with regional participation. Reviews of the 1993/94 program plans for the three sub-programs were held in March.

2.3.2 IADN Master Station Operations

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

Now into its fourth year of operation, the Point Petre Master Station of the Integrated Atmospheric Deposition Network (IADN) continues to operate nearly flawlessly. To date over 600 organic air samples, 240 total organic carbon and total suspended particles (TOC/TSP), and 240 trace element samples have been obtained at Point Petre. At the Burnt Island station on Manitoulin Island, 50 organic, TOC/TSP and trace element samples have been taken since the startup on January 1, 1992. At Egbert and ELA/Kenora, which are two potential satellite facilities in the IADN network, 460 organic, 191 TOC/TSP and 240 trace element samples have been taken.

Analysis of the samples has accelerated, and the TSP/TOC and aerosol data are complete through December 1991. Organic data from 1990 are nearing completion and interpretation of these data are continuing. Results from the trace element analysis have already shown the significant decline in lead in the atmosphere (-30% per year at Egbert and -9% per year at Point Petre) due to the elimination of leaded gasoline. Back trajectory analysis of arsenic and selenium ratios have indicated that before 1991 Noranda was an identifiable source of arsenic to the Great Lakes. Since late 1991, a process change at Noranda is showing up in the Point Petre metals data and the incidences of high As/Se ratios is decreasing.

2.3.3 Organics Analysis (Air Toxics) Laboratory

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

The primary responsibility of the Organics Analysis Laboratory (OAL) is to provide an in-house service for determining trace organic chemicals in air samples collected as part of AES activities under Annex 15 of the GLWQA (Great Lakes

Water Quality Agreement), with emphasis on target species such as PCB congeners, organochlorine (OCs) pesticides and polycyclic aromatic hydrocarbons (PAHs).

Actual measurement of the targeted trace organics in the network air samples has improved considerably during the past twelve months, with substantial progress being made particularly in the PAH analysis. For PAH analysis, the recent improvements in semi-automation of sample clean-up and data handling procedures were evident in the progress, where approximately 265 PUF and 180 GFF field sample extracts were processed. For the PCBs/OCs, GC problems and concerns with detector non-linearity meant that more time was lost: however, approximately 145 PUF and 120 GFF field sample extracts were processed. Due to the low levels of PCBs/OCs found on airborne particulate matter, the determination of these species on field GFF samples from Point Petre for 1990 employed "composites" of the extracts from the three replicate samplers.

Acquisitions were primarily directed at providing upgrades to existing analytical instrumentation and improving the efficiency of some labour-intensive steps in the procedures. In particular, the introduction of the "closed-cell" Turbovap 500 volume reduction systems in place of the rotary evaporator methods provided a considerable degree of semi-automation for this procedural step, as well as minimizing emissions of solvent vapour. The acquisition and installation of a Balston nitrogen generator system, replacing cylinder supplies for the Turbovap 50 and 200 nitrogen evaporating systems, has eliminated the need for frequent purchase and installation of pre-purified nitrogen gas cylinders.

The development of an operational GC-MS analytical capability has suffered numerous delays because of problems experienced with the HP MS-Engine system installed in late 1991. Difficulties with the field installation of extended mass capability were finally resolved in June, at which time the system was operating to expectation. However, following shutdown and temporary relocation of the system to allow for installation of the long-awaited air-conditioning , satisfactory performance could not be re-established. Extensive attempts to correct these problems were unsuccessful, despite high levels of support from HP service and applications personnel. Following considerable efforts devoted to documenting and characterizing system performance, HP were ultimately convinced to provide a complete replacement of the mass spectrometer core in March 1993. The process of specification testing and optimization is once again underway.

Significant progress has been made with the development of a multi-dimensional GC-EC method for unambiguous identification and quantitation of PCB congeners. The Siemens 2-8 unit was installed in April 1992 and optimal conditions have been established to provide resolution of PCB "clusters" which cannot be obtained by conventional gas chromatography using multiple columns of differing polarity. This method appears capable of determining trace levels of PCB congeners, which would normally be "hidden" by dominant co-eluting species; the co-planar PCBs, suspected to be responsible for the majority of PCB toxicity, are particularly amenable to this procedure.

The laboratory has also been extensively involved with the design and implementation of a series of formal interlaboratory studies for agencies participating in IADN. Working with the Quality Management Office (QMO) at the Ontario Ministry of Environment, a target list for trace elements (PCBs, OCs and PAHs) was established. OAL co-ordinated the purchase of pure organic standards which were delivered to QMO. During the year, OAL received batches of solution-phase standards from QMO for determination using our normal analytical procedures. The results of the overall study show good agreement between the participating laboratories. The performance of OAL in these studies has been highly encouraging, identifying only a few problem areas in need of investigation. The next series of interlaboratory studies are scheduled for Summer 1993; results will be published as joint AES/OME reports.

2.3.4 Atmospheric Mercury

- W. Schroeder, J. Markes and M. Shoeib

This project is part of a major AES research thrust in support of the U.S.-Canada Great Lakes Water Quality Agreement, (Annex 15: Airborne toxic substances). This Annex deals with atmospheric deposition of persistent toxic chemicals to the Great Lakes ecosystem. Mercury is one of the 11 "critical" pollutants singled out for priority action by the International Joint Commission.

Further development and evaluation was carried out (in the laboratory and in the field) with respect to improved methodologies for sampling, pre-concentration, storage and instrumental chemical analysis of airborne mercury (total vapour-phase

fraction). During June/July 1992, W. Schroeder was a guest at the GKSS Research Centre (Hamburg, Germany) where he worked with scientists in the Institutes of Chemistry, and of Physics, on a collaborative project (ENV 7 - Toxic Substances Modeling) being carried out under the auspices of the Canada-Germany Science and Technology Co-operation Programme. Activities included: inspection and selection of potential atmospheric mercury sampling sites; planning and preparations for collection and transport of mercury samples from a de-commissioned industrial site located in what used to be known as East Germany's "dirty triangle" (a heavily industrialized area around Leipzig for which reliable environmental contamination data were not available prior to German re-unification); and familiarization with the calibration procedures for the mercury analyzers employed in the laboratories at GKSS, as well as the various steps involved in the chemical analysis of environmental mercury samples. The collaborative work with chemists at GKSS has also resulted in the completion of the first of what is intended to be a series of inter-laboratory comparisons (involving exchange of information about analytical reference standards, exchange of blank and spiked collectors prepared in each of the laboratories, and chemical analyses for mercury in actual ambient air samples collected at GKSS and at AES). This new initiative is designed to test the comparability of methods currently employed in Canada and in Germany for the collection, storage and analysis of airborne mercury samples.

Work continued on data analysis of daily atmospheric mercury measurements conducted at Egbert in 1990 concurrently with other air quality measurements carried out there in connection with the Eulerian Model Evaluation Field Study (EMEFS). Data sets of pertinent meteorological and air chemistry parameters monitored at Egbert during that time period were collected and have been examined for the existence (or the absence) of correlations with atmospheric mercury concentrations. In addition, a small-scale field inter-comparison study was carried out at AES-Downsview in collaboration with staff of the OME Air Resources Branch who are evaluating/validating results obtained with a novel "continuous" mercury vapour analyzer developed by Tekran Inc. of Toronto. Reasonable agreement was found to exist between the results obtained with the two different measurement methods. Since August 1992, duplicate atmospheric mercury samples are being collected at Alert on a weekly (integrated) basis. These samples are sent to AES-Downsview for chemical analysis in our laboratory in an effort to define temporal variations in continental background levels of airborne mercury.

2.3.5 Air-Water Exchange
- W. Schroeder

Annex 15 of the 1987 Protocol to the U.S.-Canada Great Lakes Water Quality Agreement specifically calls for research on air-water exchange processes involving volatile inorganic and organic chemicals.

Utilizing an instrumental system purchased by AES, Concord Scientific has been working on the development and validation of an automated gas-chromatographic method for directly determining selected permanent gases (argon, nitrogen, and oxygen) in ambient air and in water samples. These gases are intended to be employed as "surrogate chemicals" or model substances in future studies of air-water exchange processes involving volatile inorganic and organic compounds of interest in the Great Lakes ecosystem. The draft final report "Development and Testing of a GC-Based Automated Analyzer for Gases Dissolved in Water" was reviewed and the revised final version of the project report is now available.

The other project under this heading deals with *in-situ* investigations of air-water exchange phenomena, particularly volatilization of priority organic chemicals from lakes and rivers in the Great Lakes Basin. A paper describing the laboratory testing and evaluation of two prototype devices (a sparger and a flux monitor) for application in research on air-water exchange processes has been written.

2.3.6 Smog Chamber Studies
- D. Lane

A 10 m^3 smog chamber has been manufactured at York University to study the reactions of polycyclic aromatic compounds under simulated atmospheric conditions. The "reactor committee" comprising of interested participants in the manufacture of the chamber has met several times to define the work that is to be done on the system and to locate sources of potentially available instrumentation to monitor the chamber reactions. Mann Testing Labs offered a Finnigan GC/MS to York University for use with the chamber. The instrument has been reassembled at York University, tested and assessed. Other equipment, such as flow controllers, a data logging system for the computer, gases, valves and teflon lines, were ordered. A chemiluminescent ozone monitor was loaned to the project, and will be tested and

revitalized. A NO_x monitor has been donated by Ontario Hydro.

2.3.7 PCBs in Ambient Air
- T. Bidleman and R. Falconer

This project is to measure the effect of ortho-substitution on the gas-particle distribution of PCBs in ambient air. The laboratory has been set up, and work is being repeated on previous analyses. Carbon column fractionation procedures are being rechecked, and samples analysed last summer on a DB-5 column are being re-run on the same column and also on different columns for confirmation.

Carbon column 3 fractions (non-ortho PCBs) for combined Chicago samples were analysed by high resolution GC-MS to determine concentrations of PCBs 37, 77, 126 and 169. Levels in pg/m^3 were for PCB-37: 6-11; for PCB-77: 6-8; for PCB-126: 0.78-0.83; and for PCB-169: 0.26-0.81. Percentages of PCBs 77 and 126 on particles were 3.5% and 13% respectively. The proportion of the non-ortho tetrachorobiphenyl PCB-77 on particles was nearly the same as for the di-ortho pentachlorobiphenyl PCB-110. This is in accordance with predictions based on the similarity in vapour pressures of the two PCBs.

2.3.8 Toxic Chemical Aerosol Particles
- G. den Hartog, L. Guise-Bagley, H. Neumann, J. Deary and R. Staebler

The objective was to characterize the size distribution of atmospheric particles containing toxic chemicals at a site in the Great Lakes basin. This was to be accomplished by simultaneously measuring particle size distributions with an active scattering PMS aerosol probe and toxic chemical concentrations as collected on filtering media, and then using time series analysis techniques to correlate particle sizes and toxic chemicals. In addition, low pressure high volume impactors provided size differentiated chemical analysis of the particles.

A field experiment was conducted at CARE (Egbert, Ontario) during August 1992. Particle size distributions over the range 0.07 to 5.3 μm were measured. Two PMS probes were utilized which provided size distributions of 0.07 to 0.90 μm and of 0.12 to 5.3 μm, respectively. Each probe divided the measurement range into 31 logarithmically-weighted size classes. Particle data were obtained at 60 s intervals. The University of Hannover provided a differential mobility analyzer/condensation nuclei counter system which measures particles in the range 0.01 to 0.18 μm, divided into 18 size classes. The University of Hannover also provided two Berner-type low pressure impactors for size segregation of particles and subsequent chemical analysis. A third high volume impactor was operated by AES. During the project a Gossen-type PAH monitor was also tested. Initial analysis shows a good correlation between estimated "mass" from the PMS probe results and the low pressure impactor mass, and suggests that small diameter particles less than about 0.2 μm are enriched in PAH. Impactor samples will be analyzed for PAHs during 1993, and further analysis with particle data will be performed.

2.3.9 Single Level Flux Profile
- A. Lo

The IFYGL (International Field Year for the Great Lakes) data were used in both studies carried out in the wind/wave interaction project. Results based on IFYGL data compared very well with their theoretical counterpart. This finding not only confirms the success consistency of the method, but also provides a solid measure of confidence in the quality of the IFYGL buoy data.

2.3.10 Wind/Wave Interaction
- A. Lo

The modeling methodology developed in this project has been applied to a number of research problems: its application to evaluate deposition velocity of reactive gases over an air-water interface has resulted in good success. A recent application of the methodology to the determination of the significance of relative humidity in evaluating atmospheric stratification has shown promising preliminary results.

2.3.11 Toxaphene in the Arctic
- T. Bidleman

Air and water samples from the August 1992 Resolute Bay field measurement program are being analysed for organochlorine compounds, including toxaphene. Hexachlorocyclohexanes (HCHs) are being determined along with toxaphene because of their high levels in arctic air and water, and of their probable similarity to toxaphene in their gas exchange characteristics. Concentrations of alpha- and gamma-HCH in surface water are approximately 4 and 0.5 ng/L respectively. These are within the range of HCH concentrations found in the central Arctic Ocean between 1986-87. Levels of both HCHs in air were about three times lower than measured in

1986-87. Last summer's values at Resolute were 100 pg/m^3 alpha-HCH and 8 pg/m^3 gamma-HCH. We will need to compare these to monitoring data from Alert to see if the decrease is "real" or an exceptional event for that month.

A chiral-phase gamma-cyclodextrin column from Supelco is being used to determine the enantiomers of alpha-HCH, which elute as two peaks that are nearly baseline resolved. The enantiomeric ratio (ER) is calculated as the areas of peak 1/peak 2, where the elution order from the column is peak 1 followed by peak 2. The ER can be changed only by a biological process that is stereoselective, such as an enzymatic reaction. For this reason the ER is a useful probe of microbial breakdown. European studies found ERs of 1.02-1.08 in atmospheric samples (air and rain), presumably due to a slight biological degradation of peak 2 in soils prior to evaporation, and a great depletion of peak 2 in fish and seal blubber. Another investigation showed that marine bacteria were capable of stereoselectively degrading HCHs.

The alpha-HCH standard shows an ER of 0.977 ± 0.011, close to the theoretical value of 1.00. Six air samples from Resolute Bay have ERs of 0.97-1.06 (mean = 1.00). Peak 2 is depleted in most surface seawater, for which ER is between 1.00 and 1.21 (mean = 1.08). One sample from Amituk Lake on Corwallis Island has an ER of 1.30. The results suggest that degradation of HCHs occurs in lakes and nearshore marine waters of the Arctic, but rates of this process are unknown.

A workshop on the Analytical and Environmental Chemistry of Toxaphene was held in May 1992 attended by over 80 scientists from North America, Europe and Russia to evaluate the present state of toxaphene research and recommend future directions. The workshop featured 28 presentations and posters concerning: (i) occurrence of toxaphene in animals and humans; (ii) analytical methods for environmental samples; (iii) isolation and identification of single components; (iv) worldwide usage and sources; (v) atmospheric transport and modeling; and (vi) toxicology.

A major step forward in analytical chemistry was made possible through the generosity of Professor H. Parlar and his student Dominek Hainzl from the University of Kassel (Germany). Their group has synthesized twenty different chlorinated bornanes found in toxaphene, and these analytical standards were shared among the Workshop participants. Following the formal presentations, the attendees divided into three working sessions on: analytical chemistry; environmental transport and fate; and toxicology. These groups had the responsibility for assessing the state of knowledge in their respective areas and making recommendations about research needs. Reports of these working groups, along with papers from the presentations and posters, will be published in a special issue of *Chemosphere*.

2.3.12 Northern Contaminants Research Program

- L. Barrie, R. Bailey, T. Bidleman, K. Brice, J. Kovalick and D. Toom

The objective is to measure the occurrence of selected organochlorines (OCs) and polycyclic aromatic hydrocarbons (PAHs) compounds in the Arctic atmosphere for a period of two years thereby providing insight into environmental transport, removal, transformation and surface exchange processes, as well as data for the development of realistic environmental pathways models.

As a result of a comprehensive review of the sources, occurrence and pathways of northern contaminants, it was apparent that little information existed on the occurrence in the atmosphere of OCs and PAHs. Such information is necessary if an understanding of their sources, pathways and impacts on the Arctic environment is to be achieved. There was only a few observations of the atmospheric abundance of these compounds attained through short-term intensive field studies scattered over a few years and locations.

This year routine air sampling was undertaken successfully at Alert. Routine sampling requires considerable effort in sample preparation, shipping to and from the station, and sample extraction and sample information accounting. A documented sampling protocol was prepared and a sample tracking system instituted. In addition, chemical analysis of approximately 200 extracts per year for 14 PAHs and 60 OCs was completed by the analytical laboratories at the Freshwater Institute of Canada in Winnipeg. A second site was installed at Tagish, Yukon, and sampling began in December 1992. The instrumentation of a third site in the Russian Arctic at Dunay Island was completed in February 1992.

It was shown that a robust Arctic air sampler for OCs and PAHs could function under Arctic conditions. A fourth site in the southern eastern Canadian Arctic will be selected and established in 1993/94. Reports on the results for the first year of sampling at Alert and for the first four months

of sampling at Tagish will be ready in draft by September 1993.

2.3.13 Aerial Application of Pesticides
- R. Mickle and J. Arnold

The Sevogle Experiment (AES, FPMI, NRC, RPC and UNB) carried out in September 1991 compared three widely differing emission spectra emitted for on-target deposit and off-target movement of the spray cloud. The atomizers used were the TVB (Thru valve boom), the D8-46 (hydraulic nozzle) and the Micronair AU4000 (rotary atomizer). As expected the TVB gave the highest average integrated deposit out to 200 m (88%) compared to the D8-46 (72%) and the AU4000 (61%), leaving 12%, 28% and 39% of the emitted spray still airborne at 200 m. Total drift to deposit ratios (14%, 39% and 64%) reflect the different droplet sizes in the emission spectra. However, due to the size of the droplets in each spray and the canopy characteristics, it was found that the ratio of canopy (i.e., target) to ground deposit (potential waste) was higher for the smaller droplets (TVB = 0.2, D8-46 = 0.29 and AU4000 = 0.33).

In November 1992, AES, in collaboration with FPMI and NRC, carry out an experiment at the Jornada Test Range of the New Mexico State University. From earlier LIDAR studies, the movement of the spray cloud away from the aircraft was significantly different depending on whether the spray was emitted from the upwind or downwind wings of the aircraft, and results indicated that when spraying in a cross wind situation, the spray from the upwind wing tended to deposit while the spray from the downwind wing tended to drift. If these differences were significant, then an aerial applicator could port the spray to only one wing and hence reduce drift into environmentally sensitive areas. This experiment was designed to quantify these differences for meteorological conditions from stable to unstable at aircraft heights of 10 and 30 m. During the nine trials of the study, an extensive array of ground samplers out to distances of 600 m from the spray line sampled the deposition. Also vertical profiles of the drifting cloud were taken at 200 and 600 m downwind of the spray line. Presently, the sampler analyses are being carried out in the NRC laboratories but early indications suggest that there is a significant difference in the deposition and, consequently, drift from the upwind and downwind wings.

Work continues towards testing a generic approach to be used in the registration of pesticides for aerial application. RPC has completed the second year of the data base contract. Presently, the data base format has been finalized and the data base itself contains 47 references with a total of 257 subsets of experimental results. The data base will be released base back to the original contributors requesting that it be updated by the individual research groups. The ongoing commitment will be that RPC will maintain the data base on a cost-recovery basis and maintain the responsibility of updating the data base each year based upon the return information from the clients. The value to the clients is that they will gain access to an extensive data base with extraction capabilities to produce specific sub-sets based upon selected criteria for statistical analyses. This year, RPC carried out characterization studies for deposit shapes based on spray parameters. A generic approach for establishing buffer zones has been developed which will utilize the results from the RPC contract. The generic approach is based on the operational spray scenario including application rate and field width. Given the tolerable off-target deposit as a ratio of the application rate, the appropriate buffer given the field width can be determined from a simple nomogram. Over the next year, the method will be tested for a number of operational spray scenarios to see the effects on off-target ratios. In the mean time, the data base will also be used to assess a number of existing spray drift models. Ultimately a model could be used directly to calculate appropriate buffer zones given the operational scenario and the sensitivity of an appropriate off-target receptor.

2.3.14 Emission Inventories Development
- E. Voldner

A fundamental requirement of the Air Toxics Program is to develop inventories of the sources of toxic chemicals. In contrast to the tropospheric ozone issue, which is regional in scale, toxic chemicals emitted to the atmosphere have a wide variety of physical and chemical characteristics which, along with meteorology, dictate whether they will settle out close to the source or will be carried for hundreds and thousands of kilometers. Thus, for many persistent toxic chemicals it is necessary to know their sources on a global basis.

There are a number of international activities underway in which Canada is an active participant. The International Biosphere Program, for example, has a Global Emissions Inventory Activity (GEIA) to compile emissions globally. The countries involved have recognized the need to have a Centre with an ongoing responsibility to maintain and upgrade emissions information. The UN ECE

Task Force on Potentially Toxic Pollutants also acknowledges this need, although current activities are focussed on obtaining some useful information. Similarly the Arctic Monitoring and Assessment Program of the circumpolar countries acknowledges the importance of assembling large scale inventories to support the monitoring activities that are underway.

On a more local geographic scale, the International Joint Commission recognizes that atmospheric transport of toxic chemicals to the great Lakes Basin is important and that control of such toxics will depend on taking action on an international basis to reduce emissions.

To address the above needs as well as the requirement for emissions data to be used in modelling, an embryonic Canadian Centre for Global Emissions is being established. In 1992/93 work has focussed on working with a number of consultants to collect global data bases of a variety of chemicals. Beyond this, preliminary global inventories of SOx/NOx and toxaphene have been established. An inventory on lead is in preparation with support from the Nordic Council of Ministers.

Unfortunately, there are a number of issues beyond the scientific which make such work difficult. Many countries simply do not have emissions information and many more (including Canada) have some restrictions on information on some toxic chemicals. Data are provided often only in hard copy and quality assurance is difficult.

In addition, the methodology for making traditional compilations of point source emissions simply is not appropriate for considering pesticides, for example. When considering pesticide emissions it has been necessary to develop fundamentally new methods of approaching the emisions problem. An air/surface exchange model has been developed to simulate exchange of semi-volatile organic compounds. This has led to the quantification of the revolatilization of pesticides under varying conditions.

Models are beginning to be used to assess the sources of contaminants to Lake Superior and the distribution of contaminants in the ecosystem and ecosystem response to potential reductions in inputs.

2.4 CLIMATE CHANGE

2.4.1 BOREAS

- G. den Hartog, H. Neumann, N. Trivett and R. Mickle

The Boreal Ecosystem-Atmosphere Study (BOREAS) is a multinational field and analysis study involving elements of land surface climatology, tropospheric chemistry and terrestrial ecology. The goal of BOREAS is to improve our understanding of the interaction between the Boreal forest biome and the atmosphere in order to clarify its role in global change. BOREAS has been planned jointly between the United States (NASA, NOAA, NSF and EPA) and Canada (EMR, DOE, FC, AC and NRC). The major field effort of the study will begin in 1993 and will continue through 1994.

During the summer of 1992, activities included the inspection and selection of the major field sites near Prince Albert, Saskatchewan, and Thompson, Manitoba. At each of these locations several satellite sites were selected to cover the range of major surface types of the boreal forest. Preparation of these sites for field measurements commenced the fall of 1992. At present, involvement will be directed toward measurement of exchanges of heat, momentum and trace gases, such as CO_2, N_2O and CH_4. The proposal is linked with proposals from the University of Guelph, the University of British Columbia and the University of Georgia. The broader objectives of the combined proposals include determination of the annual cycle for carbon and nitrogen at the site, with trace gas measurements now also including CO, NO, NO_2, NH_3 and, possibly, terpenes.

2.4.2 Polar Sunrise 92 - I

- L. Barrie

An international collaborative experiment, Polar Sunrise 1992, was organized at Alert in the Canadian Arctic from January 15 to April 20, 1992, involving six nations. It was recognized by the International Global Atmospheric Chemistry (IGAC) Program as a project of the Polar Atmosphere and Snow Chemistry Activity (PASC).

The objectives were twofold: first, to investigate nightime chemical and physical reactions in the Arctic troposphere and the impact on northern hemispheric oxidant formation; and, second, to better understand the role of marine halogens and heterogeneous reactions in the lower tropospheric ozone destruction at polar sunrise. Issues related

to the objectives included: (i) chemistry of nitrogen oxides in the atmosphere; (ii) chemical changes in the Arctic troposphere at polar sunrise and, in particular, the relative influence of anthropogenic versus oceanic compounds and the role of heterogeneous chemistry; (iii) processing of lower tropospheric pollution at high latitudes; and (iv) effects of meteorology on surface baseline air chemistry observations.

During the study period there was an enhanced measurement program throughout the period with two intensive efforts: a dark-period one January 18 to February 15 and a light-period one April 1 to April 20. The dark-period intensive constituted the first characterization of the lower tropospheric composition in the absence of sunlight that has ever been made. In the past, all previous studies mounted by Canada or other countries have been made in total sunlight during late March and April. The light-period intensive not only involved a ground level intensive effort but also measured vertical profiles over the Arctic ocean north of Axel-Heiberg and Ellesmere Islands. In addition, it included surface observations of air composition at a camp 200 km to the northeast of Alert on the Arctic ocean pack ice.

It was confirmed that there was the periodic disappearance of lower atmospheric ozone at Alert at polar sunrise associated with particulate Br production. At the Arctic ocean surface 200 km north of Alert, the frequency of ozone loss was much higher than at Alert.

Chlorine was clearly implicated in polar sunrise chemistry by observations of the selective destruction of hydrocarbons and alkylnitrates, and the production of formaldehyde and acetone. However, it cannot explain ozone depletion, leaving bromine as the prime candidate.

The budget of atmospheric bromine was calculated from measurements in air of total bromine and of individual compounds. On average, $CHBr_3$, CH_3Br, and the sum of CH_2Br_2, CH_2ClBr, $CHClBr_2$, and $CHCl_2Br$ comprised 23, 44 and 5% of gaseous organic compounds, respectively. Bromoform and its chlorinated counterparts were correlated and peaked during ozone depletion episodes.

Aircraft observations over the Arctic ocean ice at 400 m confirmed the widespread destruction of ozone in April and made, for the first time, vertical profile measurements of several gaseous compounds.

2.4.3 Polar Sunrise 92 - II

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

The objective for this study was to provide aerosol physical measurements using optical probes as described in the Toxic Chemical Aerosols Particles (2.3.8). Two Berner-type impactors and a Differential Mobility Analyzer were also used in this study. These systems then provide a full range of aerosol size measurements from 0.01 to 12 μm and the ability for comparison between different instruments, ensuring reliability of the measurements.

The field portion of this study was completed in April 1992. Data was obtained nearly continuously from January 19 to April 20th. The optical probe data has a time resolution of 30 s. The measurements in April 1992 showed that aerosol concentrations are possibly correlated with ozone for very small particles, whereas they are inversely correlated for larger particles.

2.4.4 Polar Sunrise 92 - III

- K. Anlauf and A. Wiebe

For the periods January 15 - February 15 and April 1 - 20, 1992, O_3, NO, NO_2 and NO_y were measured at the Alert surface laboratory site. Data abstraction has been completed and some of the major findings are: (1) good agreement in ozone measurements between the BAPMoN laboratory and the Special Studies laboratory; and (2) both NO and NO_2 were very low during both periods (NO was usually below the detection limit of about 25 ppt; NO_2 was in the range $<=$25-150 ppt in winter and $<=$25-100 ppt in the spring period; NO_y was about 500-600 ppt in spring).

2.4.5 Polar Sunrise 92 - IV

- S. Li

Since April 1992, the samples collected at Alert during the Polar Sunrise 92 experiment have been analyzed by ion chromatography (IC) and instrumental neutron activation analysis (INAA). Currently the results are being analyzed with the objective of defining their relationships to the ozone depletion events.

The total inorganic bromine, as determined from the denuder-filter pack sampler and IC analysis (with confirmation by a filter pack charcoal trap sampler), consists of aerosol particulate bromine, gaseous phase HBr and BrO. Additional species, not measured during the study, may include Br_2, HOBr and $BrNO_3$, but are probably at relatively

low levels (at least during the dark period) compared to the above species. The total organic bromine, determined from the charcoal trap and analyzed by INAA, consists of bromoform, methyl bromide, chlorobromomethane, dibromomethanes and several others which were determined using GC-MSD and HPLC. Currently, an effort is underway to assess the changes in compositions of the total inorganic and total organic bromine as related to ozone change and solar radiation changes during the study.

Nitrous acid (HONO) was sampled on the denuder-filter pack system and analyzed by IC-UV. HONO was observed to be about 20 ppt in the dark phase with an episode of up to 70 ppt. In the light period, HONO dropped to about 8 ppt on average. This level of HONO is significant in that it provides a strong OH source in the light period for photochemistry through rapid photolysis. On the other hand, the rapid photolysis suggests a rapid formation mechanism for HONO. Currently, all evidence suggests that the formation is through heterogeneous processes, perhaps involving halogen nitrates.

Additional effort is being made to summarize other results from these sampling systems, including the results on aerosol sulphate, nitrate, nitric acid and other aerosol species. Currently, additional IC analyses are being carried out on other samples from Polar Sunrise 92, including aircraft samples, cascade impactor samples and snow samples. The purpose of the filter exposure experiment is to determine what bromine species are collected on various types of filter media under simulated Arctic conditions. This experiment will be carried out in conjunction with H. Niki of York University.

2.4.6 MSA in the Arctic
- S. Li

Two papers based on the methanesulphonate (MSA) time series from the Arctic have been written. The first deals with the quantification of the contribution of marine biogenic sources to aerosol sulphate in the Arctic on a seasonal basis, as well as an accurate determination of the fractions of MSA and sulphate from dimethylsulphide (DMS) oxidation. The latter is a very important parameter in the understanding of potential climate effect of marine DMS emissions. In the second paper, the long term trend and seasonal cycles of MSA are analyzed using the spectral analysis technique of digital filtering. MSA has been found to have decreased by 26% over the 1980-1991 period. In addition, there appears to be a small perturbation of background MSA levels that may be related to the quasi-biennial oscillation. Furthermore, MSA variations appear to be related to sea surface temperature variations in the source region.

2.4.7 Alaska Field Study
- S. Li

A paper, summarizing results from an earlier field study carried out at Barrow, Alaska, was written that describes the relative proportion of water-soluble organic compounds in aerosol particles relative to that of sulphate, and the climatic implication of the soluble organic compounds.

2.4.8 Gas Standards Laboratory - Carbon Dioxide
- D. Ernst, N. Trivett and L. Leeder.

The central calibration system for CO_2-in-air standards used at the three Canadian Baseline Monitoring sites has seen many improvements. The system was modified to minimize the penetration of moist air from the room into the system, a more stringent quality control protocol was adopted for calibration analyses, and an investigation into methods of improving precision was initiated.

All CO_2 calibration data generated from 1987 to the present was entered into a customized Paradox database. The database was upgraded to provide graphical representation of the drift for each CO_2 standard, and to allow for correction of concentration values using non-linear regression techniques.

Results of an international CO_2 intercomparison, coordinated by NOAA, show that AES CO_2 standards are in good agreement with the international scale. The three standards that were evaluated (340, 350 and 375 ppmv CO_2) were within 0.03, 0.07 and 0.41 ppmv, respectively, of the NOAA standards.

A draft copy of a manual outlining maintenance procedures for the instrumentation at the three field sites is nearing completion. A more regularly scheduled maintenance program will be implemented with the aim of reducing instrument down times.

2.4.9 Gas Standards Laboratory - Methane
- D. Worthy and M. Rauh

Development work continued on the analysis of CH_4 and CO_2 from grab flask samples. The precision of the Gas Chromatographic (GC)

CO_2/CH_4 measurements was improved by increasing the GC's sample loop volume from 1 mL to 3 mL. Analysis of methane from the same pressurized flasks used in the CO_2 program will begin in late 1993.

AES participated in a second round-robin CH_4 standard intercalibration study of a NOAA CH_4 standard. The tank was calibrated by AES, two Japanese agencies, Scripps (University of California) and NOAA. NOAA will report the complete findings of the round-robin in a report which will be released in 1993. AES also calibrated two CH_4 standards for the Italian program.

2.4.10 Gas Standards Laboratory - Freon
- D. Worthy and M. Rauh

The development of a GC system, which is capable of measuring CO_2 and CH_4 using an FID detector, and F-11 and F-12 using an ECD detector, has been completed. The precision ranges for F-11 and F-12 compare favourably with the precision ranges attained by NOAA on their continuous monitoring GC systems. This system was installed at the Alert BAPMoN station in April 1993. The old system, which measures only CO_2 and CH_4, will be removed after a one month overlap period with the new system and will be modified to include freon measurements.

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

Weekly flask sampling continued at Sable Island and Alert. The weather station at Cape St. James was automated in August 1992 and, as a result, it was necessary to terminate the flask sampling program. AES collected weekly flask samples from Cape St. James from May 1979 to August 1992. In early spring of 1992, two sites were investigated as replacement sites for Cape St. James. The sites are Cape Scott, on the Northern tip on Vancouver Island, and Estevan Point, on the west coast of Vancouver Island. Flask samples are currently being collected at both these sites, and a decision will be made in 1993 as to which site will replace Cape St. James in the flask sampling network.

A pressurized flask sampling unit was constructed and installed at Estevan Point in December 1992. The new double stopcock flasks which were designed last year are used for this new flask sampling program. The new pressurized protocol enables us to collect enough sample in each flask for both CO_2 and CH_4 analyses. The original grab sampling program will also continue at Estevan Point for intercomparison purposes. A joint Canadian - Australian Carbon Isotope program will begin at Estevan Point in May 1993. International cooperative flask sampling programs with Germany, United States, Russia and Australia continued at Alert.

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

Some of the experiments from the Polar Sunrise 92 experiment have become a regular part of the BAPMoN program. The combination of these extra tasks, a new snow sampling program and the initiation of a data flagging routine, has increased the workload at the station beyond the capability of one technician. In September 1992, the first co-op student was hired to assist the technician. Every four months, a new co-op student will be hired and sent to Alert to assist the BAPMoN technician.

The continuous CO_2 and CH_4 monitoring programs are running smoothly. A new database for the CO_2 calibrations has been completed. The Alert methane ^{14}C and ^{13}C and ^{85}Kr isotope programs, established in August 1990, is continuing. For this program, special sample bags are slowly filled over a period of 2 weeks to get an integrated sample of the ambient air. This sample is then extracted from the bags into 14.7 L aluminum tanks using a compressor. These tanks are sent monthly to Toronto where the CH_4 and krypton are cryogenically extracted and transferred into smaller 2 L aluminum tanks to be sent to Germany for isotope analysis. A new compressor, which operates without oil, was installed for the sample extraction, and has resulted in successful elimination of the contamination problem that was being experienced with the old compressor. A Gossen PAH analyzer, to be used to characterize which parcels of air are influenced by camp emissions, was also installed at Alert.

In September 1992, the existing Alert laboratory facility was expanded to approximately 6 times its original size, a total area of 240 m^2. The extra space was required for the installation of more gas analysis equipment, storage and emergency accommodations.

2.4.13 Sable Island Operations
- N. Trivett, D. Ernst, D. Worthy and J. Hopper

A pilot study to evaluate Sable Island as a possible future background air chemistry monitoring site is currently underway. It is a cooperative effort between AES and NOAA. The NOAA group is responsible for the aerosol program and AES is responsible for the greenhouse gas program. Installations of continuous CO_2 monitoring equipment for the greenhouse gas program were carried out in August 1992. Air is sampled from the top of a 10 m tower approximately 10 m southwest of the main office. Special conditioning of the sample is necessary due to the high humidity levels at this Maritime location.

2.4.14 Fraserdale Operations
- N. Trivett, D. Ernst, D. Worthy, M. Rauh, L. Leeder, J. Kovalick and J. Hopper

The measurement programs for greenhouse gases and aerosols are continuing. A carbon isotope program for CH_4 was set up at Fraserdale in December 1992. It is a cooperative program between AES and the University of Heidelburg. The air is sampled only from the wetland sector. This monitoring should help define the isotopic fraction of the CH_4 emitted from the wetland areas. A three-week intensive study, including radon measurements, is planned for the summer of 1993.

2.4.15 Data Analysis and Capability
- S. Racki, N. Trivett and D. Worthy

A dedicated data collection computer was added to both the Fraserdale and Alert stations. The dedicated data collection computers download data from the dataloggers directly and are more effective than the dial-up method used previously. The old system is still used as a backup and for the daily monitoring of the measurement systems' performance.

Throughout 1992 upgrades were made to the computer capabilitites, with the most notable being the replacement of our NEC 386 with an AST 486 server which is faster and has a much greater capacity. It was designed to be easily and cost effectively upgraded when needed. To increase productivity, four workstations were upgraded to a 486 level and future plans include the move to new 150 Mb Bernoulli drives and cartridges. A 1 Gb magneto-optical drive is on order that will be put on our server which will greatly ease our constant need for temporary storage and will free up the faster hard disks for other uses.

2.4.16 Canadian - Chinese Bilateral Agreement
- N. Trivett, D. Worthy and M. Rauh

A bilateral agreement between Canada and China was reached in the Spring of 1992. Canada committed to help the Chinese establish a Global Atmosphere Watch (GAW) Baseline Observatory on Walliguan Mountain. AES has already purchased two GCs for the GAW station for the measurement of CO_2, CH_4 and CO. Plans are to continue to aid the GAW staff in the development, installation and operation of the GCs at the Chinese GAW station. Two Chinese scientists will develop the systems at AES under the supervision and direction of AES staff.

AES has also contributed and installed two stand-alone remote weather stations and a standard CAPMoN collector for precipitation at the GAW station. They have also agreed to help the Chinese set up permanent meteorological measurements on the newly-constructed tower at the GAW station.

2.4.17 Sulphate Aerosol Global Distribution
- J. Pudykiewicz and A. Dastoor

Not only do volcanic eruptions play an important role in the global sulphur cycle of the Earth's atmosphere by significantly perturbing the global atmospheric chemistry, but also the large amount of sulphate aerosol produced by the oxidation of SO_2 injected into the atmosphere during volcanic eruptions has a relatively big influence on the radiative equilibrium of the Earth's climatic system. The submicron particles of the sulphate aerosol reflect solar radiation more effectively than they trap radiation in the infrared range, thereby cooling the Earth's surface. The modification of the global radiation budget following volcanic eruption can subsequently cause significant fluctuations of atmospheric variables on a subclimatic scale.

The resulting perturbation of weather patterns has been observed and well documented since the eruptions of Mt. Krakatau and Mt. Tambora. The impact of the sulphate aerosol from volcanic eruptions on the radiative equilibrium of the Earth's atmosphere was also confirmed by the studies done with Global Circulation Models designed to simulate climate. A simple and effective method to estimate the global distribution of the sulphate aerosol is proposed using a dynamic global model of the atmosphere coupled with the system of mass conservation equations for atmospheric trace species. The chemistry of the model is represented by the right hand sides of the

mass conservation equations for atmospheric tracers.

To increase the realism of the simulation, the clouds in the calculations are represented by cloud cover, cloud liquid water content, precipitation and a flag indicating the type of clouds. The parameterization employed follows the method of Sundqvist. The dynamic model with representation of clouds and sulphur chemistry is used to generate the tropospheric and stratospheric distribution of the sulphate aerosol. The special attention given to clouds and accurate representation of the source term is motivated by the need to bridge the gap existing between climate models and models traditionally employed for simulation of the air chemistry.

For the June 1991 eruption of Mt. Pinatubo in the Philippines, the large amount of SO_2 injected mostly to the stratosphere was an important factor perturbing the chemical and radiative equilibrium of the Earth's atmosphere. It was speculated that this particular eruption would offset observed trends in global warming. The experimental data collected following the eruption of Mt. Pinatubo provides a unique opportunity to evaluate the numerical techniques used in simulation of atmospheric chemistry, and to enhance the understanding of the influence of volcanic forcings on the atmosphere. The recent investigation of a 1000-year record of glaciological data provides a significant justification for this type of research, particularly in the context of the recent interest in predicting the variability of the atmosphere on climatic and subclimatic scales.

The Aerosol Optical Thickness (AOT) of the simulated distribution of sulphates produced by the eruption of Mt. Pinatubo shows relatively good agreement with observations. This fact is an important indication that the global sulphur budget, in the first approximation, could be simulated relatively well by a simple chemistry scheme. Evaluation of the model-calculated AOT field also shows that the size distribution of the fine particles measured following the El Chino eruption applies quite well to the case of Mt. Pinatubo. The measurements confirm that this cloud contained mostly submicron particles. The actual spectra in the Mt. Pinatubo cloud were, however, strongly variable. The general conclusion, which could be drawn from comparison of the simulation with observations, is that the optical properties of volcanic clouds are described well by a Mie scattering on submicron particles.

2.5 STRATOSPHERIC STUDIES

2.5.1 Ozone Monitoring

- J.B. Kerr, W.J. Clark, J.J. Bellefleur, F. Karpenic, D. Tarasick and R.H. Hoogerbrug

Three new sites for monitoring stratospheric ozone with the Brewer instrument were established at Winnipeg and Halifax in July 1992, and at Montreal in January 1993. These additions bring the number of ground-based sites to eleven.

As a result of the heightened concern regarding depletion of stratospheric ozone, the UV (ultraviolet) index program was launched in May 1992. This program involves the forecasting of a UV index value for the next day to provide the public with information regarding UV levels. Measurements of ozone and UV-B radiation from the ozone monitoring operation played a key role in the development of this new program. The program complements the OZONE WATCH program which was launched in March 1992 and advises the public on the state of the ozone layer.

The Stratospheric Ozone Observatory at Eureka, NWT, became operational in early 1993 with the Lidar measurement of stratospheric ozone and aerosols. The ozone sonde operation was expanded to include measurements at Eureka.

Brewer Umkehr analysis software has recently been installed on computers in Finland, Greece, the United States, and Switzerland via Internet. This new capability to make the software readily available to users all around the world should have a significant impact on the quantity and quality of Umkher ozone profile data which are available to the ozone research community.

2.5.2 Stratospheric Research

- H. Fast, D.I. Wardle, R.H. Hoogerbrug, K. Nassim, J.J. Bellefleur, F. Karpenic, C. Midwinter, W.J. Clark and A. Ullberg

Altitude profiles of nitric acid, Mount Pinatubo aerosols, and ozone were derived from data obtained on the 7th Canadian Ozone Experiment (CANOZE 7) held at Alert, NWT, in the winter of 1991-92.

In preparation for CANOZE 8 a stratospheric balloon campaign was conducted in September at Vanscoy, Saskatchewan. The purpose of the balloon flights was to test a number of modifications to the compact radiometer (miniradiometer) built by Scientific Instruments

Ltd., and to test the latest version of the nitrogen dioxide sondes developed by Unisearch.

CANOZE 8 was held at Alert to obtain altitude profiles of stratospheric nitric acid with the compact radiometer, of aerosols using the University of Wyoming backscatter sonde, and of ozone. This balloon campaign was conducted in two phases. The first phase took place in November 1992 before the polar vortex cooled to temperatures of -80^{0}C and lower: temperatures at which polar stratospheric clouds (PSCs) start to form. The second phase was conducted throughout January 1993. Preliminary analysis of the backscatter sonde data indicated the presence of PSCs on at least one or two balloon flights. The compact radiometer flights took place within several hours of the backscatter sondes. All balloon flights also carried ozone sondes.

In cooperation with the Meteorological Research Institute (MRI) of Japan, a Bomem interferometer (0.004 cm^{-1} resolution) was installed at the new Stratospheric Ozone Observatory at Eureka, NWT. This new system was used during March 1993 to record atmospheric absorption spectra using the sun as the light source. From the spectra the column densities and altitude profiles of hydrogen chloride and of hydrogen fluoride will be determined. The interferometer measurements will be included in the database of the Network for the Detection of Stratospheric Change (NDSC). A Bomem interferometer was set up for testing at CARE (Egbert, Ontario) for recording atmospheric emission.

2.5.3 Aircraft and Space Experiments

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

The SunPhotoSpectrometer (SPS) and Airglow Imaging Radiometer (AIR) developed by the Experimental Studies Division were flown successfully as the SPEAM-2 experiment (SunPhotoSpectrometer Earth Atmosphere Measurement) on the US Space Shuttle flight STS 52 in October 1992. Canadian astronaut Dr. Steve MacLean operated the instruments as part of the CANEX-2 (Canadian Experiments) mission. The SPS made measurements of the visible part of the solar spectrum as the sun rose through the Earth's atmosphere due to the spacecraft's motion. These data will be analyzed in the coming months using atmospheric modelling software to produce altitude distributions of several stratospheric constituents. These constituents include molecular oxygen, ozone, nitrogen dioxide and aerosol. The long-term goal of the experiment is the monitoring of stratospheric composition and the calibration of instruments which are permanently deployed in space.

Work on the Brewer Earth Atmosphere Measurement (BEAM) experiment is continuing and a launch of the instrument is expected in 1994 or 1995. The Getaway Special Container preparations are nearing completion at Bristol Aerospace, and the final configuration of the Brewer instrument, which is being built up at the AES, has been defined. The experiment focusses on the problem of relating ground- and space-based observations of atmospheric ozone, and on monitoring the long-term performance of ozone instruments permanently situated in space.

A version of the SPS instrument specifically designed for use on the NASA/Ames ER-2 stratospheric research aircraft was built in 1992. It flew on the ER-2 during the engineering test flights of the SPADE (Stratospheric Photochemistry, Aerosol and Dynamics Expedition) mission. The experiment provides measurements of the absolute intensity of light at the flight level of the aircraft. These data are used to calculate the rate at which light breaks apart the various gases found at high altitude in the atmosphere. This information is used to improve the accuracy of chemical models which are used to interpret composition data collected by the other instruments flown on board the aircraft. The flights are sponsored by the High Speed Research Program office of NASA. The ultimate use of the chemical information accumulated is in the assessment of the possible impact of a future generation of supersonic transport aircraft.

Within a few months, a Brewer Ozone Spectrophotometer may be flying as a non-paying passenger on the regularly scheduled Aeroflot flight between Montreal and Moscow. In a project jointly developed by C.T. McElroy of the AES and Nikkolay Elansky of the Institute of Atmospheric Physics of the Academy of Sciences of Russia, an Ilyushin aircraft will be modified to include an upward viewing window so that ultraviolet light from the sun can enter a Brewer Ozone Spectrophotometer mounted inside the cabin of the aircraft. The data obtained during flights over the pole, and possibly elsewhere in Russia, will supplement measurements made by the ground-based Brewer network, and will provide particularly good calibration data for the Total Ozone Mapping Spectrometers mounted on the US Nimbus Spacecraft and the Russian METEOR satellite.

A major component of the initiative called the Canadian High Altitude and Mobile Platforms (CHAMP) is the construction of a Differential Absorption LIDAR (DIAL) for the airborne measurement of ozone. The primary goal of the development program is the contribution of a significant research capability to the global-scale effort to understand the processes which control ozone destruction in the Arctic winter and spring. These measurements will complement the data collected at the Stratospheric Ozone Observatory at Eureka, NWT. In a significant new step toward the execution of this major research project, the National Center for Atmospheric Research (NCAR), in the United States, has indicated an interest in sharing the cost of the project and in participating jointly in aircraft studies of the Arctic ozone layer.

2.5.4 National Atmospheric Radiation Centre

- L.J.B. McArthur, D.I. Wardle, T.Grajnar, A. Arama and E. Wu

The Centre continued to focus on the calibration and characterization of solar and infra-red radiometers as part of its WMO Regional Radiation Centre responsibilities. A major field effort to update the responsivity of the Centre's standards was undertaken during the months of September and October at the CARE facility (Egbert, Ontario). A major research component in this area has been the development of a standard means of characterizing instrument response to temperature changes. Over 300 instruments were calibrated for the network and outside agencies during the year. The increased interest has lead to the deployment of 4 broadband UV-B instruments for testing. Comparisons of these instruments have been made with the Brewer Spectrophotometer.

The Baseline Surface Radiation Network station at Asquith, Saskatchewan, was closed. Property was leased and approval was obtained from municipal officials to develop a new site at a more appropriate location south of Regina. An environmental assessment was completed successfully.

A contractual agreement was reached with the University of Calgary to set up an International Illumination Commission (CIE) daylighting station in conjunction with the Department of Environmental Design. Installation of the site occurred late in the year. Cooperative efforts in the measurement of aerosol optical depth continue with the University of Sherbrooke.

2.6 CORE RESEARCH

2.6.1 Flow Over Complex Terrain

- J.L. Walmsley and W. Weng

The MSFD-PC model, developed in collaboration with Prof. S. R. Karpik, University of Toronto, is now in a user-friendly package ready for distribution. The model can be run on 386 or 486 computers and produces results in minutes to hours, depending on the grid size and computer speed. A number of peripheral programs are included in the package for preparation of the input topographic and roughness fields, and for displaying the output. The results can be presented as contour plots at constant height above terrain, as cross-section plots at any orientation in the constant-height plane, or as vertical profiles at any point within the model domain.

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. The MSFD output is being coupled with Hunt's (1985) thin plume approximation to calculate the dispersion from an elevated pollution source and the resulting surface concentration.

The MS-Micro/3 model was applied to Roundtop Mountain, near Sutton, Quebec, to estimate acid deposition from precipitation and fog. Customized wind fields were produced in collaboration with Prof. H.A. Bridgman, University of Newcastle, Australia. Computer programs were written to use the wind fields for calculating acid deposition, in collaboration with Prof. Bridgman and Dr. R.S. Schemenauer.

The MS-Micro/3 model code was sold to 7 groups in 6 countries. The "Guidelines" program for estimating wind speed in complex terrain distributed to 13 groups in 7 countries. The "Wind Profile over Sea" and "Wind Correlation" programs were sold to 5 groups in 3 countries.

2.6.2 Wind Energy

- J.L. Walmsley

Draft standards were prepared and edited for Canadian Standards Association (CSA) Subcommittee F428. After incorporating comments from the Subcommittee members, the standards will eventually appear as a CSA

document titled *Recommended Practice: Site Assessment for Wind Energy Conversion Systems - Meteorological Aspects*.

Activities on the Wind Resources Assessment Steering Committee, jointly sponsored by EMR Canada and SaskPower, involved preparation of a "Request for Quotation" for a contract to undertake a wind energy resource assessment for southwestern Saskatchewan.

2.6.3 Gaussian and Heavy Gas Research
- C.S. Matthias

A model which simulates the release of a pressurized fluid jet has been completed and submitted for publication. The emerging liquid partially boils, with the remainder falling to the ground (contiguous liquid and large droplets), or shattering and remaining suspended as small droplets. The jet entrains air, evaporates more liquid, and the mixture temperature falls well below the boiling point. The model compares well with data. The model serves as a step in defining the source term for the rupture of a tank containing a pressurized liquified gas. The output then serves as a step in defining the gas flow rate for a dispersion model.

A transition model is being developed to allow the moderate speed jet mixture of gas, air and droplets to decelerate to the ambient wind speed. It will also determine the point at which jet turbulence yields control of the entrainment process to atmospheric turbulence (neutral buoyancy dispersion model) or to buoyancy controlled turbulence (dense gas model). Temperature, density, gas and droplet flow rates are calculated.

As part of a response to assess the impact of H_2S emissions from an industrial facility, a state-of-the-art dispersion model was developed by selecting components from recent literature. The model uses surface layer and mixed layer similarity theory to describe boundary layer parameters. A Gaussian framework is retained. It is superior in principal to the traditional Pasquill-Gifford approach which was designed for application over a grassy surface having a roughness length of 3 cm and albedo of about 20%. The model compares favourably with data.

Some preliminary work has been done to develop a model to estimate the mixed layer height using routine meteorological hourly data. "The most difficult parameters to estimate accurately are the mixing heights: z_i for the CBL and h for the SBL. Unfortunately, these are also the most important parameters for many applications." (Gary Briggs and Francis Binkowski, *Research on diffusion in atmospheric boundary layers: a position paper on status and needs*.)

2.6.4 Rocket Sonde Development
- E. Wilson and D. Lane

The object of the project was to demonstrate that rockets (initially low level hobby rockets achieving altitudes of 300 m or more) could transport meteorological sondes to useful altitudes and that signals could be received from the rocket on its descent to the ground. Several types of rockets were obtained, built and modified to carry the transmitter from the Address Met Sonde System. Tests were carried out at the King Radar location and at Transport Canada's TCTI facilities in Cornwall. It was successfully demonstrated that a hobby rocket could launch a modified meteorological payload and that the signals from the rocket could be received at ground level during the descent of the rocket. Since these rockets can be used many times, great cost savings may eventually be realized by this new approach.

The results have attracted considerable attention, with the result that it is proposed to continue the development of the concept, and to redesign and miniaturize the complete meteorological sonde for use on rockets which can achieve altitudes of 3,000 m or more.

2.6.5 Reactive Atmospheric Tracers Transport
- J. Pudykiewicz

To provide a semi-Lagrangian simulation of the transport of reactive atmospheric tracers, this project, in collaboration with P. Smolarkiewicz of NCAR, addresses a class of finite difference approximations to the evolution equations of fluid dynamics with chemical terms. These approximations derive from elementary properties of differential forms. Values of a fluid variable at any two points of a space-time continuum are related through the integral of the space-time gradient along an arbitrary contour connecting these two points (Stokes' theorem). Noting that spatial and temporal components of the gradient are related through the fluid equations, and selecting the contour composed of a parcel trajectory and an appropriate residual, leads to the integral form of the fluid equations, which is particularly convenient for finite difference approximations. In these equations, the inertial and forcing terms including chemistry are separated such that forces are integrated along a parcel trajectory (the Lagrangian aspect), whereas

advection of the variable is evaluated along the residual contour (the Eulerian aspect). The virtue of this method is an extreme simplicity of the resulting solver; the entire model for a fluid may be essentially built upon a single one-dimensional Eulerian advection scheme while retaining the formal accuracy of its constant-coefficient limit. The Lagrangian aspect of the approach allows for large Courant number computations of reactive atmospheric flows.

Theoretical considerations are illustrated with examples of applications to selected classical problems of atmospheric fluid dynamics with chemistry terms. An accurate representation of multiple point sources is one of the crucial issues in numerical simulations of atmospheric reactive flows. A simple, yet accurate, approach based on the mathematical foundations underlying semi-Lagrangian methods for fluids is presented. In the continuous limit, point sources contribute to the total solutions through the trajectory integral of Dirac delta functions. A blunt application of numerical methods characteristic of grid-point models usually suffers from either excessive truncation errors associated with finite-difference approximations of unresolved features or excessive parameterization errors associated with approximating delta functions with unrealistically broad source regions. The approach adopted improves the overall accuracy of computations, as it admits narrow source distribution functions (with parameters depending on micrometeorology of emitted plumes) whose contributions to the solutions are integrated analytically along the trajectories intersecting source regions. This approach has been applied in simulations of burning Kuwaiti oil fields and proved itself accurate and useful.

During the past year the semi-Lagrangian algorithm was used for solving several problems pertinent to atmospheric chemistry modelling. One of the most important application of atmospheric tracer models is the simulation of chemical reactions of species emitted to the atmosphere from various industrial activities. Sulphur, nitrogen and hydrocarbons are the most commonly simulated chemicals. Their importance is mostly in the context of tropospheric ozone chemistry. Several preliminary simulations of the high ozone concentration episodes indicate good performance of the numerical method in the context of simulation of atmospheric chemistry.

2.6.6 Simulation - Convective Boundary Layer
- J. Pudykiewicz

From the view point of numerical technology, the Bousinesq equations employed to simulate the convective boundary layer with chemical reactions (Large Eddies model for chemically reactive flow) constitute a prototype of fluid systems where the evolution equations are supplemented with diagnostic relationships leading ultimately to elliptic equations characteristic of a boundary value problem. In this context, the example of convective boundary layer investigated in this project is representative of a variety of dynamical applications. The purpose of the example is manifold: it illustrates design and performance of the numerical solver for a class of problems addressed, it documents ability of the algorithm to resolve fine structures of highly nonlinear fluid motions with chemical reactions, and it exposes advantages of large-Courant-number advection admitted by the semi-Lagrangian approach.

2.6.7 Cloud Modelling
- A. Dastoor

The objective is to provide an accurate prediction of 3-D cloud liquid water content, cloud amount, total cloud cover and precipitation rate in a large-scale global atmospheric model to improve the cloud-radiation interaction and the modelling of the aqueous-phase chemical processes of the atmospheric tracers.

A Sundqvist convective and stratiform condensation scheme, including cloud water content as a predictive variable, has been implemented in the global model. The scheme allows partial cloudiness and condensation associated with the layer clouds in the model grid boxes. Cloud water prediction and cloudiness estimation consistent with the condensation processes are the important features of the scheme. Sensitivity experiments have been conducted to evaluate the impact of cloudiness parameterization on the model forecast. The cloud cover has been verified using satellite data.

It is shown that the total cloud cover is better estimated as the sum of separate estimates of convective and stratiform cloudiness within the framework of the condensation processes parameterized in the model. The convective cloud cover is found to be very important to the radiative budget. An improvement in the model forecast, hydrological balance and cloudiness prediction is noticed when the stratiform relative humidity threshold decreases with height. The study also

presents a new 3-D view of the cloudiness estimated by the original scheme and provides a simple vertical and horizontal sub-grid scale cloud cover parameterization. Vertically sub-grid stratiform clouds combined with horizontally sub-grid convective clouds provide a remarkable improvement in the estimation of total cloud cover.

2.6.8 Dynamic Global Atmospheric Tracer Model
- A. Dastoor and J. Pudykiewicz

The Canadian global spectral forecast model has been modified to permit the dynamic treatment of an arbitrary number of passive scalars. In this form the model is flexible to simulate the global transport of any number of atmospheric tracers for a variety of applications. The physical and chemical processes related to the tracers can be added to the transport equations in the model.

Deficiencies in using spectral approach or the conventional high order interpolating semi-Lagrangian schemes in advecting mass fields with strong gradients were examined. A 3-D semi-Lagrangian scheme coupled with a limiting procedure has been adapted for the passive transport. The scheme is of high order in the domain of sufficiently smooth solution and is able to suppress the wiggles generated by the high-order interpolation in the vicinity of the strong gradients of the solution.

2.7 AIR QUALITY SERVICES

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

The PC-Version of AQPAC, developed under joint venture with MEP, has been improved with the inclusion of the effect of roughness of terrain on the nature of diffusion in all four dispersion models. Furthermore, the models were modified such that they are now applicable for point, area and volume sources. This PC-AQPAC has been verified with our bench mark system. Some minor errors were identified and they have to be corrected. This version 1.0 has been distributed to all AES Regions for comment and for suggestions for improvement. The Regions have used this version in their emergency exercises and in some real accident cases.

2.7.2 Mesoscale Model (BLFM)
- S.M. Daggupaty and R.S. Tangirala

The three-dimensional mesoscale boundary layer forecast model (BLFM) was further modified with the inclusion of detailed surface temperature prediction using the "Force - restore" method of Bhumralkar and Deardorff. Extraction of land-use data at 1 km resolution is almost completed. Further work is under progress to test the efficacy of surface similarity layer formulation against full time integration equations in the 10 m layer above surface. Combining the mesoscale model with AQPAC's source-strength and puff-trajectory models will enhance the BLFM's potential applications to multitude of air quality problems, such as prediction of pollution episodes, detailed forecast of hourly circulation and turbulence information (hazard areas) over complex terrain, and coastal and marine areas for oil and chemical spills.

2.7.3 Atmospheric Tracer Model Application I
- J. Pudykiewicz

The release of radioactive materials from nuclear testing could be identified and evaluated using atmospheric tracer models which were developed during the past 10 years. The examples provided by the successful application of this type of model for tracing of radioactive debris from the Chernobyl nuclear accident provides interesting and scientifically credible basis for this task. There are two different scenarios which should be considered when the tracer model is applied for detection and identification of the source of radioactive release. In the first case, the model is integrated forward in time to predict the distribution of the radioactive material in the atmosphere using the preliminary data provided by a seismic network, and the measurements of radioactivity of air and rain samples. In the second case, the model is integrated backward in time to reconstruct the location, time dependence and strength of the source using the initial conditions provided by the measurements of radioactivity of air and rain samples. The first application is relatively well established in the operational activities of meteorological services, which were implemented following the Chernobyl accident in 1986. The second application of the model is much more challenging. Previous experience indicates clearly, however, that it is feasible to use the tracer model also as a means of assessment of the source properties from the distributed measurements of the activities of air and rain samples.

In the case when the tracer model is integrated forward in time, the accident scenario could be obtained from a separate computer model simulating the dynamics of the discharge of the radioactive or chemical species. A simpler

solution is related to the use of the accident scenario from "look up tables" containing descriptions of the most typical potential accidents. In the case when the model is integrated backward in time, the source parameters will be calculated to minimize the sum of squares of the differences between model predicted and observed specific activities. The parameters to be found as a solution of this minimization problem will include: coordinates of the source, vertical extent and the time dependent intensity of the release. The problem of venting in this context is relatively simple because the time dependence of the release could be described by a delta Dirac function of time and the major parameter describing the source term will be the amount of material released to the atmosphere.

2.7.4 Atmospheric Tracer Model Application II
- J. Pudykiewicz

The importance of computer simulation techniques in atmospheric chemistry is underscored whenever a large amounts of anthropogenic materials are released into the atmosphere. These materials can create adverse environmental effects and even perturb the radiative equilibrium of the atmosphere in some cases. A spectacular example of this type of influence was the recent catastrophic release of pollutants from burning Kuwaiti Oil Fields. The study of this particular event can provide a better understanding of the limitations of the numerical techniques used in the study of atmospheric transport processes. This is particularly important in the context of the numerical simulation of releases of industrial pollutants into the atmosphere.

The main concern following the onset of the Kuwaiti oil fields fires was the potential climatic consequences of the atmospheric aerosols produced by combustion. The speculative scenarios stipulated a severe perturbation of global weather patterns, changes in the Monsoon cycle and a substantial cooling trend over the following months. Experiments with hemispheric and global tracer models performed immediately after the onset of the fires indicated that the initial assessment of the global impact of the release of contaminants from Kuwait was greatly exaggerated because of an overestimation of the amount of the release of particulate matter and of errors in the calculation of the albedo of aerosols produced by the combustion process of oil. The regional impact of the release of pollutants from the Kuwaiti oil fields remained, however, very serious and presented one of the most severe deteriorations in air quality in modern time.

The global scale model was used as a tool to assess the environmental impact of the release from the Kuwaiti oil fields. The results obtained from this research clearly indicated that the global scale effects are negligible mostly because of the relatively small mass of the release and of the fact that the release is confined mostly to the lower part of the troposphere.

Furthermore, the mass of pollutants transferred to the stratosphere by the Kuwaiti oil field fires is negligible when compared with that of recent volcanic eruptions. According to current estimates, the potential effect of the Kuwaiti source is much less important than the effect of the Mt. Pinatubo eruption. It is estimated that the release of SO_2 from Kuwait between March and October 1991 was between 3 and 10 million tons, whereas the eruption of Mount Pinatubo injected about 20 million tons of SO_2 into the stratosphere in two weeks. In addition, the Kuwaiti release was confined to the lower part of the troposphere where effective removal mechanisms transfer the contaminants to the surface. Therefore, the link between the Kuwaiti oil field fires and an increase of the particulate matter and SO_2 in the stratosphere is tenuous at best, casting doubt on the alarmists scenarios derived from the studies performed a decade ago in the context of the so-called "nuclear winter".

Initial simulations indicated that the potential local scale effects of the Kuwaiti source could be extremely severe. This conclusion clearly indicated the need to employ a computer tool other than a global tracer model or climate model, which have inherent limitations in the horizontal and vertical resolution, making them impractical for regional scale studies. In light of the initial assessment of the release from the Kuwaiti oil fields fires, it was decided that further research should be focused mostly in the region of the Middle East, and the numerical simulation of the dispersion processes should be performed using regional scale atmospheric tracer models. This type of research is an important part of the effort to evaluate atmospheric transport models, and to increase our understanding of atmospheric chemistry.

2.7.5 RDMQ System
- B. Sukloff

The objective of RDMQ (Research Data Management and Quality Control) is to create software allowing a scientist to perform quality control and data management on air quality data in a robust, documented and timely manner. Work began on the project in October 1992. A

project plan document was presented to the ad hoc data base management committee in November 1992. A consensus was reached that there is enough commonality among the various air quality networks in the Branch to justify a prototype system to be developed as a base model. The committee agreed to proceed with the project. A detailed description document was completed by March 1993. System programming will commence in April 1993 with a prototype system ready by July 1993.

2.7.6 Air Quality Services
- M. Still

In June 1992, the AES Environmental Assessment Coordinating Committee (Chair: R. Cross) met to exchange information on how AES meets its obligations to the EARP (Environmental Assessment Review Process) mandate, to better appreciate the role of C&P and FEARO (Federal Environmental Assessment Review Office), and to address the issue of standardization of EARP specialist advice by AES. The main EARP activity by the Branch was in providing modelling expertise to the Regions through evaluation and verification of approriate air quality models. The Branch also supplied a list of items, relating to air quality, to be considered when reviewing environmental assessment documents.

In the Fall of 1992, visits were made by Hans Martin and Malcolm Still to all the AES Regions with the objective of advancing the process of consolidation between research in the Branch and research in the AES Regions. It was noted that all Regions were working with many partners on a full range of service and research projects involving air quality issues in their Region. Two general comments were that the Regions would like a clearer definition of the role of each Service in the region, and that the Regions would like to be more involved in national projects on air quality issues that may not affect them directly.

In 1992, AES decided to add more air quality training to the 1992/93 Meteorologists' Course. The Branch supplied subject material and lecturers for the 4 days. To support the AES initiative to produce Distance Learning training through the use of video tapes, the Branch has supplied material and presenters for the air quality topic.

2.8 REGIONAL AIR QUALITY REPORT

2.8.1 AES Regional Activities

Information on joint AES regional activities with the Branch can be found in the combined regional Quarterly Reports (Volume 10, Number 1 to 4).

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AIR QUALITY RESEARCH BRANCH

ANNUAL REPORT

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AROI	**MODELLING & INTEGRATION RESEARCH DIVISION**		FAX: 739-4288	
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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) 421-4758	Dorval
		DERCO, S.	4856	4S602
		DORLING, S.	4692	3S505
		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
		SIROIS, A.	(514) 421-4674	Dorval
		SOBKOWICZ, C.	(514) 421-4759	Dorval
		SUMMERS, P.	4204	3S510A
		TANGIRALA, R.S.	4671	4S626
		VOLDNER, E.	4467	4S313
		WALMSLEY, J.	4861	4S608
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		RPN Dorval	FAX: (514) 421-2106	
AQP	**PROCESSES RESEARCH DIVISION**		FAX: 739-5708	
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	Secretary	YURKIEWICH, D.	4841	4S305
		ALEXANDROU, N.P.	4600	4S124
		ANLAUF, K.	4840	4S520
		BIDLEMAN, T.	5730	4S106
		BRICE, K.	4601	4S123
		BROOK, J.R.	4916	3S503
		DEARY, J.	4460	4S421
		DEN HARTOG, G.	4860	4S609
		FUENTES, J.	4233	3S609
		GAUDENZI, A.	4863	4S303
		GUISE-BAGLEY, L.	859-5122	Egbert
		HAHN, J.	859-5122	Egbert
		HAYDEN, K.	5733	4S303
		HECK, P.	859-5122	Egbert
		HOFF, R.	859-5122	Egbert
		KERMAN, B.	(416) 336-4798	CCIW
		KOSHYK, N.	4862	4S307
		LANE, D.	736-5425	York
		LI, S.M.	5731	4S312
		LIAO, L.	4473	4S125
		MACDONALD, A.M.	4465	3S502
		MARKES, J.	4875	4S420
		MICKLE, R.E.	4851	3S506
		MORAN, M.	5762	3S510
		NEUMANN, H.	4858	4S603
		RIDAL, J.	(416) 336-4798	CCIW
		SCHROEDER, W.	4839	4S521
		SHEPPARD, A.	859-5122	Egbert
		SHOEIB, M.	4251	3S610
		STAEBLER, R.	4859	4S604
		SU, K.	4873	4S419
		TANG, H.	736-5427	York
		THAM, Art	4844	4S304
		WATT, M.	4846	4S304
		WIEBE, A.	4837	4S310
		WOODHOUSE, S.	859-5122	Egbert
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	Secretary	SAUVE, M.	4454	4S407
		AHMED, S.	4845	4S627
		AKKUR, N.	4236	3S504
		BARRIE, L.	4868	4S107
		BEAUREGARD, L.	736-2100 x40503	York
		CAPMoN Manager	4450	4S404
		BOTTENHEIM, J.	4838	4S309

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	CHAN, D.	4852	4S405
	CHORNEY, V.		ALERT
	ERNST, D.	4462	1S201
	GALLANT, A.	736-5211	York
	HIGUCHI, K.	4452	1S201
	HOPPER, F.	4872	4S410
	HUDEC, V.	5761	1S201
	IQBAL, S.	4458	4S418
	KESSLER, R.	736-2100 x40503	York
	KOBELKA, W.	4461	4S421
	KOVALICK, J.	4876	4S420
	LANCE, N.	736-2100 x40503	York
	LEEDER, L.	4462/6555	1S201
	MACTAVISH, D.	736-2100 x40502	York
	ORD, D.	4457	4S625
	POISSANT, L.	4250	3S610
	RACKI, S.	5719	1S201
	RAUH, M.	4462/6552	1S201
	RO, C.	4455	4S411
	SHARMA, S.	736-2100 x40500	York
	SHAW, M.	4456	4S625
	SUKLOFF, B.	5722	4S401
	TOOM, D.	4874	4S419
	TRIVETT, N.	4447	1S202
	UNDERWOOD, M.	4459	4S418
	WALLGREN, E.	6557	1S201
	WORTHY, D.	4683	1S201

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	AWACHIE, R.	4631	4S111
	BARTON, D.V.	4195	4S202
	BELLEFLEUR, J.J.	4948	Rooftop
	CLARK, W.J.	4628	4S422
	FAST, H.	4627	4S205
	GRAJNAR, T.	4633	4S110
	HALL, B.	4624	4S423
	HARE, E.	4635	4S220
	HOOGERBRUG, R.H.	4625	4S207
	KARPENIC, F.	4636	Rooftop
	KERR, J.B.	4626	4S206
	MCARTHUR, B.	4464	4S201
	MCELROY, T.	4630	4S203
	MIDWINTER, C.	4629	4S204
	NASSIM, K.	4760	4S220
	TARASICK, D.W.	4623	4S221
	ULLBERG, A.	4706	4S422
	WU, E.	4256	Rooftop