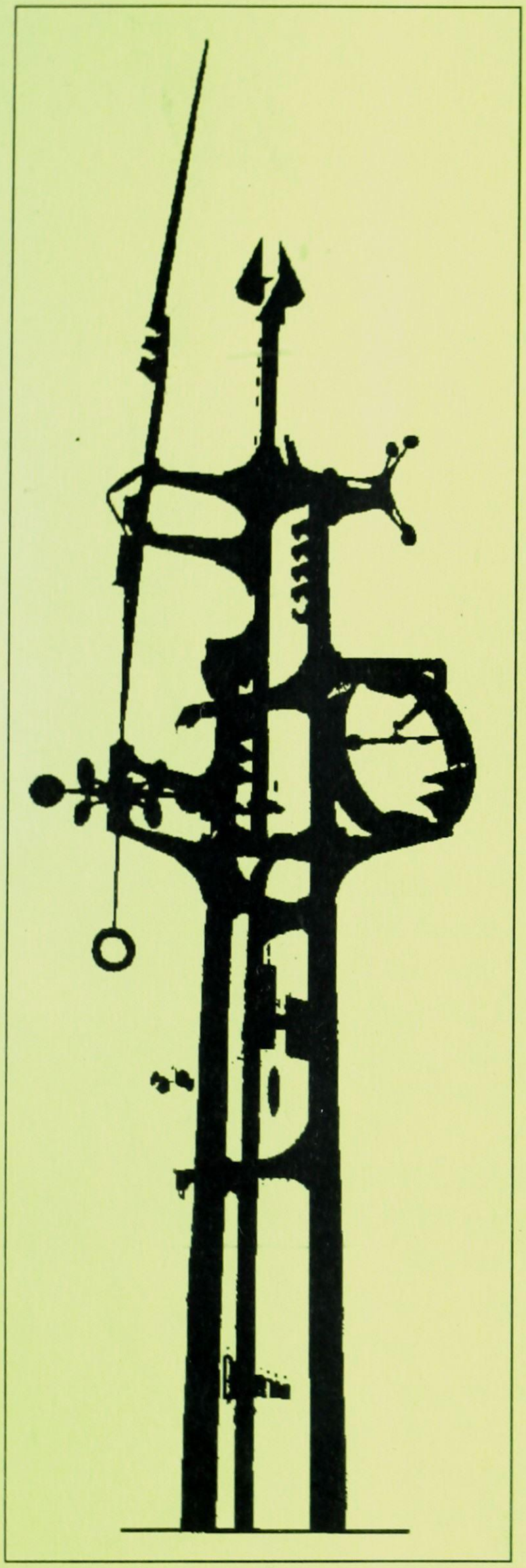

AIR QUALITY

RESEARCH BRANCH

ANNUAL REPORT

1997-98

Compiled by
Lorraine Kiely

February 2000

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

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1.0 FOREWORD

1.1 AIR QUALITY RESEARCH BRANCH

[D.C. McKay]

The Branch has been involved in a full and varied research program looking at air quality issues. Even though the report details results in the individual issue areas, these atmospheric issues are inter-related with each other, as well as being inter-related with the other portions of the environment. Therefore, projects are undertaken in partnership with colleagues from other organizations and from different scientific disciplines, not only in Canada but worldwide.

As of January 1998, the Branch's tropospheric ozone research program (NOx/VOC Science Program) was merged with the Acidifying Emissions Deposition research program. The result was the Acidifying and Oxidant Program. The reasons for this merger were twofold. Scientifically, both the tropospheric ozone research program and the acidifying emissions research program deal with the oxidizing capacity of the atmosphere. Strategically, both programs are relatively "mature" and following major assessments in both areas in 1997 it was more efficient to put these programs together.

Particulate matter effects human health and visibility. Human health studies have shown that aerosols have an influence on the health of humans through the relationship of hospital admissions to the level of aerosols in the atmosphere. To understand more fully the effect of aerosols on the environment, the Branch has moved into particulate matter research through investigations of particle size effects and of their relationship to light scattering and to deposition.

Chemical and physical atmospheric observations are important in defining the temporal and spatial trends in atmospheric conditions. The Branch has many sites throughout Canada where atmospheric constituent measurements are being made. These measurements are augmented by data from other agencies and from intensive short-term field studies. Even though the Branch focuses on several air quality issues, all issues are inter-related and so are the data. Efforts are being made to consolidate the monitoring network so as to gain the most data from the resources available and to provide integrated data sets for analysis.

The measurement campaign to monitor and study chemistry and dynamics of the arctic stratospheric ozone layer continues at Eureka. While data analysis on the past winter's measurements have just begun, results are expected to be interesting in view of the unusually warm atmosphere over Eureka which prevented Polar Stratospheric Clouds (PSCs) to form. This is in contrast to the previous winter when observations of PSCs were frequent and persisted well into March.

1.2 AWARDS

[L. Kiely]

Since 1988, the Branch has presented the All-Seasons Research Award to staff who have forwarded the goals of the Air Quality Research Program. To date, 34 such awards have been presented, including staff from other sections of Environment Canada. In 1997, two employees were recognized for their work:

- David Ord and Tom Mathews who produced a new version of a software package that spatially interpolates and maps measurement data. This package, NAtCon, is the mainstay of the National Atmospheric Chemistry Data Base and Analysis System (NAtChem). The new version of NAtCon was programmed by Tom, and tested and evaluated by David. Both individuals contributed many hours of their personal time to produce this new version. As a result of this work, the NAtChem group has been able to increase its mapping and interpolation productivity, to increase its range of capability, and to save approximately $10,000 per year on software licence fees. This award is in recognition of David's and Tom's personal commitment to this project, and of their contribution in advancing the Branch's goals and in increasing NAtChem's productivity and capability.

1.3 CARE

[F.A. Froude]

The Centre for Atmospheric Research Experiments (CARE) is an experimental site where atmospheric data is collected for a variety of long-term and short duration studies involving air quality programs, climate research and ecological monitoring. The laboratory and field facilities support our research programs, as well as those of the Ecological and Health Division (Burlington), the Environmental Protection Service (Ottawa), the Ecological Monitoring and Assessment Network (EMAN), plus several universities.

Data are collected using in-situ surface measurements and remote sensing techniques for high altitude measurements. The measurements are taken as part of established networks while other measurement are taken as part of a stand-alone project. All measurements are available to collaborative researchers subject to approval of the principle investigator.

Work continued on the development of airborne and mobile LIDAR systems. An active fog collector was redesigned and deployed in Atlantic Canada to collect data on chemical pollutants in fog water. Instrumentation to measure total gaseous mercury and particulate matter was installed at the two Canadian Integrated Atmospheric Deposition Network master stations, Point Petre and Burnt Island. Modified commercial instrumentation for the measurement of NO_x, PAN, SO_2, O_3 and CO is being installed as part of the air quality CORE site upgrades. These instruments will be added to the existing online instruments to provide real-time species concentration data.

An Intranet web site to display real-time data is available for selected instruments. This feature provides the user with the ability to view instrument parameters, combine plots, average data over different time periods, and download this data. More information is available by contacting the manager, F. Froude, at (705) 458-3302 (frank.froude@ec.gc.ca).

1.4 PROGRAM REPORT

[K. Ford, D. Biasi]

The Branch began its 1997-98 fiscal year with a complement of 107 employees. During the year we hired two research scientists, a stable isotope chemist and an atmospheric chemistry technician. By the end of

March 1998, taking into account the departure of 15 of our staff under the Work Force Adjustment Program, our Branch consisted of 95 permanent and term employees.

Twelve post-doctorate fellows worked on various scientific programs during the year. In addition, several visiting scientists and guest workers from around the work participated in scientific and research studies. The Branch hired 45 students from various colleges and universities. Branch staff participated in the following conferences and meetings: 82 internationally; 128 in the U.S.A.; and 280 in Canada.

The Branch began the year with an initial allocation of just over $12,900K, which was comprised of $5,600K for salaries, $6,100K for operational costs, and $1,200K for capital expenditures. In addition to this allocation, the Branch received about $3,800K from other organizations to aid research activities. The additional funding included $2,050K from the DOE Strategy Capital Fund, $541K from DOE Ontario Region for the Great Lakes Action Plan, $239K from DIAND for the Northern Contaminants Program, and $439K from PERD to fund seven PERD projects.

1.5 BRANCH RESEARCH ACTIVITIES

1.5.1 Flow Over Complex Terrain
[J.L. Walmsley]

Improvements to the Guidelines for Estimating Wind Speed Variations in Complex Terrain were undertaken using PERD funding under a Collaborative Research Agreement with Professor Peter Taylor of York University. Work has focused on refining the speed-up estimates for stably-stratified flow over two-dimensional isolated hills and on developing interpolation formulae to allow inclusion of those estimates in the Guidelines software. Dr. Jim Salmon of Zephyr North has also been collaborating in this project through his development of a Windows95 user-friendly version of the software.

At the moment, the stable-stratification guidelines are based entirely on calculations with a more sophisticated model, MSFD-STAB. If there is further support, comparisons with wind tunnel and/or field data will be made, with work extended to include three-dimensional terrain features.

1.5.2 Wind Energy
[J.L. Walmsley]

In collaboration with Dr. Jim Salmon of Zephyr North, a conference paper describing tests and applications of the Wind Correlation Model of Walmsley & Bagg (1978) was presented. An expanded version was submitted for journal publication. The associated software provides a capability to relate short-term wind speed and direction measurements at a candidate wind-turbine site to long-term wind climatology at a nearby weather or climatological station. The method has wider application to the general case of two-site correlation of winds.

1.5.3 RDMQ System
[B. Sukloff, R.Vet]

The Research Data Management and Quality Control (RDMQ) Software System was developed by the Branch to assist in managing and quality controlling research data. A number of research projects, both within and outside the Branch, used RDMQ for this purpose.

The Atlantic Region's Mercury monitoring program used RDMQ in a pilot study. Enhancements to the quality control procedures were developed based on the pilot study. RDMQ was implemented for the

CAPMoN (see 2.1.2) air filter measurements. The system will be run in parallel with the current system for data from the first quarter of 1998, after which QA/QC will be performed exclusively through RDMQ. The Environmental Health Division, Environment Canada Ontario Region, Burlington, Ontario, initiated a pilot project to use RDMQ to quality control water chemistry data.

The United States Environmental Protection Agency continued to use RDMQ to quality control data from the Lake Michigan Mass Balance project. A contractor started to quality control the historical U.S. and Canadian IADN chemistry data. The IADN meteorological data are being quality controlled routinely weekly.

A joint project with the NAtChem Data Base (see 2.1.4) and Analysis Facility was undertaken to develop a new standard for exchanging environmental measurement data. It is known as the NAtChem Data Exchange Standard. The NARSTO Quality Systems Science Centre has adopted this as its preferred data transfer format.

1.5.4 Ceilometer/Wind Profiler Comparison

[K.B. Strawbridge, R. Rogers, N. Donaldson]

In October, a modified Vaisala Ceilometer and a wind profiler were set up. There were a variety of conditions from clear, clean air to hazy polluted air, and a variety of cloudy conditions. The main purpose was to evaluate ceilometer sensitivity to the detection of aerosols, boundary layer heights and optically thin, as well as higher level, cloud. This data set is being analyzed in conjunction with the MERMOZ II dataset for boundary layer determination.

1.5.5 CFDE III

[G.A. Isaac, S. Cober, J.W. Strapp, K.B. Strawbridge, I. Gultepe]

During the airborne lidar redesign phase there was sufficient interest to develop additional detection channels to measure depolarization. This new capability to determine particle sphericity was of particular interest during the Canadian Freezing Drizzle Experiment (CFDE) III. The airborne lidar was operated on 7 different days during December 1997. The primary objective was to fly at altitudes greater than 3.6 km over target areas of interest and then descend to collect in-situ data. The CV580 was outfitted with a variety of cloud micro-physical probes, including particle imaging probes, FSSP probes yielding cloud droplet distributions, ASASP probe to measure particle distributions, icing probes and a complete meteorological package. Ground support for the experiment included a Multiple-Field-Of-View lidar at Trenton, Ontario, an upper air sounding system at Ottawa airport, and a network of radars.

The primary goals of CFDE III were to characterize aircraft icing environments, to validate current forecasting models, to test and inter-compare several icing detectors, and to improve capability for identifying regions of potentially hazardous icing using remote sensing instruments. CFDE III provided an excellent opportunity to test the sensitivity of the new airborne lidar system and identify cloud layers and in some cases even cloud phase. The upward lidar and corresponding depolarization channel identified incredible cirrus cloud structure.

2.0 THE ISSUES

2.1 ACIDIFYING EMISSIONS

2.1.1 Aerosol Optical Properties & Visibility

[R. M. Hoff, L. Guise-Bagley, K. McDonald, I. Campbell, Z. Nejedly (U. Guelph)]

Under the Acid-Rain program, four stations for assessing visibility reduction were installed (Vancouver, BC; Waterton Lakes, Esther, AB; Egbert, ON; and St. Andrews, NB). The focus has been to obtain size-segregated aerosol concentrations and optical measurements (light scattering and absorption), aiding in the determination of the aerosol characteristics (size, speciation, and growth) which impact on the atmospheric visibility issue.

The data analysis from the first four years has been completed and those results have been presented. These analyses have shown that the proportion of sulphates, organics, soil, and black carbon in the aerosol across Canada varies, but not as much as one might suspect. Unlike Vancouver, which shows a large hydrocarbon and black carbon basis, the other three stations all show appreciable sulphate contribution to both $PM_{2.5}$ and to visibility reduction. Recent work has shown that nearly all (90-110%) of the visibility budget can be attributed to the above four components plus nitrates in air. Organics are an appreciable portion of the light scattering budget at all sites.

The St. Andrews station has been moved to a location near Toronto to obtain paired observations at this urban location and the rural Egbert site for a period of two years. The intent is to determine the level to which transportation sources contributed to the urban air $PM_{2.5}$ and visibility budget in Ontario. It is often thought that sulphate was the dominant scatterer in the East, but this may not be strictly true.

2.1.2 CAPMoN

[D. MacTavish, N. Lance, R. Braga, B. Kessler, C. Brunski, W. Kobelka, D. Ord, EC Regional Inspectors]

The Canadian Air and Precipitation Monitoring Network (CAPMoN) operated directly or in partnership 10 air filter measurement sites and 22 precipitation chemistry sites between April 1, 1997, and March 31, 1998. December 31, 1997 marked the closure of the Island Lake, Manitoba, site that had been re-opened in 1997 in partnership with Manitoba Environment. EC Regional staff maintained the majority of CAPMoN's on-site Field Operations. This included a regular calibration/inspection program. Overall network integrity was ensured by comprehensively auditing operations at 13 sites.

Partnerships continue with Nova Scotia Environment and the Northwest Territories Government in the operation of two precipitation chemistry monitoring sites. Temporary cost-sharing agreements were reached with Pacific and Yukon, Prairie and Northern, Ontario and Atlantic EC Regions allowing for the continuation of 4 precipitation monitoring sites.

The Branch initiated the Canadian Network for Isotopes in Precipitation, a cooperative effort between CAPMoN and the University of Waterloo, to investigate the stable isotope composition of precipitation in Canada. Excess precipitation samples from 10 sites were composited into monthly samples and on-site sample collection was started at four CAPMoN sites in January 1998.

Chemical analyses and the compiling of CAPMoN laboratory data sets for the 1997 network samples were completed that included the analyses of over 17,500 filters and 7,200 precipitation samples - more than

140,000 chemical determinations. Laboratory credibility was maintained by continued successful participation in international intercomparison studies managed by Environment Canada's NWRI/NLET, the WMO-GAW Laboratory, the United States Geological Survey, and the Norwegian Institute for Air Research.

Zero level QC (ZeroQCnet) of CAPMoN air filter measurement data transferred by telemetry was reviewed, expanded and further automated. CAPMoN and Regional staff are now able to access and review site-specific air filter data and graphs via the Intranet.

2.1.3 CAPMoN Data Quality

[R. Vet, M. Shaw, B. Sukloff, S. Iqbal, A. Sirois]

The Canadian Air and Precipitation Monitoring Network (CAPMoN) data were quality assured under the auspices of the CAPMoN Quality Assurance Program, and were fully quality controlled and finalized within the required deadlines. Formal performance audits were carried out at all filter pack and ozone sampling sites, and at several precipitation monitoring sites. A formal audit report was produced. An updated Annual QA Report was drafted and the precipitation chemistry data were submitted to the National Atmospheric Chemistry (NAtChem) Database. The ozone data were submitted to the NAPS Database. Long-term trend analyses of the CAPMoN data were carried out.

2.1.4 NAtChem/Precipitation Chemistry

[R. Vet, C.U. Ro, D. Ord, A. Sirois]

The activity of the National Atmospheric Chemistry Data Base (NAtChem) and Analysis Facility focused on several initiatives, including NAtChem web site development, publication of analysis results, workshop for Asian scientists and NAtChem user support.

The NatChem Precipitation Data Base was successfully updated to 1995 for all major Canadian and US precipitation chemistry networks, except the Ontario Acidic Precipitation In Ontario Study (APIOS) Network which was not submitted to NAtChem.

The NAtChem web site was newly designed and implemented to accommodate information on the networks, sites, data, analysis results, publication listings and annual reports. The first version of the 1995 Precipitation-Chemistry Annual Report was posted on this web site.

A workshop on Canadian Acid Deposition Monitoring and Research was hosted for a number of Asian scientists in June 1997. The workshop provided an opportunity for information transfer on the topics of atmospheric chemistry monitoring, data management, QA/QC and analysis techniques to the acid rain community in Asia.

NAtChem staff completed Phase 1 of a 3-phase project designed to combine climate data with precipitation chemistry data to produce highly resolved spatial maps of wet deposition. In Phase 1, the staff investigated various statistical techniques (e.g., co-Kriging), investigated U.S. and Canadian climate data sets, and identified a first set of suitable Canadian climate data.

The NAtChem Facility responded to 52 data and analysis requests. Precipitation chemistry data from Canada and the USA were thoroughly analysed to obtain long-term trends (1980-94) of acid deposition patterns and to estimate the gross long-range transport of air pollutants from the US to Canada. Temporal variations were examined by looking at the changes that occurred in the spatial patterns of wet deposition

in North America and integrated wet deposition in eastern North America between the early 1980s and the early 1990s.

2.1.5 Trajectory Modelling

[B. Pabla]

The project objective was to maintain AES trajectory models, to develop and maintain their graphical user interface and necessary data archives, to assist AES users of the trajectory models, and to compute trajectory data on a cost-recovery basis for other research organizations. Scientists frequently use the results from the trajectory model to explain the transport pathways of various chemical pollutants.

The northern hemispheric model (Olson Trajectory Model [OTM]) can compute backward or forward trajectories starting from any point on the northern hemisphere for the period from 1978 to present. A new, more detailed terrain field was acquired from the Canadian Meteorological Centre and implemented for 190.5-km version of OTM, improving calculations of trajectory over mountainous and coastal areas. Trajectory data were provided to organizations from the U.S.A. (NASA and University of Hawaii) and Germany.

A global trajectory model (Pudykiewicz Trajectory Model [PTM]) was modified to compute trajectory data for 17 years for 57 sites across Canada. The PTM was used in support of the Air Quality Prediction Project, where daily forecasts of ground level O_3 were made for the Southern New Brunswick area.

2.1.6 Fogwater Deposition

[J.L. Walmsley, N. Urquizo, W.R. Burrows, R.S. Schemenauer, J.R. Brook]

The objective was to estimate liquid water content (LWC) at the Chemistry of High-Elevation Fog (CHEF) site (845 m MSL) on Roundtop Mountain in southern Quebec from routine meteorological measurements at the Sherbrooke weather station (238 m MSL), 78 km to the northeast. The CHEF site was chosen because LWC observations were available for validation purposes.

The scheme that worked best was a hybrid of applications of two regression schemes: Classification and Regression Trees (CART) and Neuro-Fuzzy Inference Systems (NFIS). This hybrid method achieved a correlation coefficient of 0.810 and accuracies of 0.962 and 0.664 for no-fog and fog events, respectively, and a total accuracy of 0.923. These measures of skill were significantly better than those from initial estimates, or from schemes that used CART alone. Attempts are now being made to extend the method to other elevations to obtain estimates of the spatial variability of LWC and, ultimately, fogwater and acid ion deposition.

2.1.7 Smog Chamber Studies

[A. Wahner (KFA-Juelich, Germany), W.R. Stockwell (Fraunhofer Institute, Garmisch-Partenkirschen, Germany)]

AES and two German institutions collaborated to study the formation of particulate nitrate using the KFA-Juelich particle chamber. Growth of ammonium nitrate particles for different initial sulphate/nitrate concentrations of aerosols is to be attempted within the chamber. The data will be used to verify parameterizations used within the AES particulate matter model currently under construction. The work is a new direction for the KFA team and concentrates on determining appropriate analytic procedures to generate and measure particle nitrate formation. Active scattering probes (PMS) and an Anderson Impactor were contributed from AES for use in the Juelich laboratory. Chamber tests showed that the number densities within the chamber exceeded the design limitations of the probes, but the subsequent

purchase of additional instrumentation by the Juelich group will allow measurements in the same size range. Tests of procedures for the analysis of the filters are currently underway, with advice provided by D. MacTavish.

2.1.8 Airborne Lidar System

[K.B. Strawbridge, M.G. Harwood]

A modification to the National Research Council of Canada's Convair 580 (CV580) was completed to allow simultaneous upward/downward lidar capability. The re-design also included the addition of depolarization channels for both orientations. This new capability will enhance the ability to detect aerosol and cloud structure below and above the aircraft with increased sensitivity.

Due to structural limitations of the CV580 airframe, it was necessary to redesign the airborne lidar system. The previous system was downward only and pointed 8 degrees off nadir due to the location of fuselage openings. To double the lidar instrumentation while keeping the weight to the same as the old system required each component to be selected based on the best combination of performance and physical size/weight.

The Camac 8 bit data acquisition system was replaced with a Gage 80 MHz 12-bit computer card that can run either single channel 80 MHz. or dual-channel 40 MHz modes. The dual channel mode offers the capability to record either dual wavelength or depolarization data.

The dual rod 10 Hz laser was replaced with two single rod 20 Hz lasers. Each laser has a self-contained closed loop cooling system, power consumption of less than half that of the old system, and a beam diverger unit to expand the beam to meet eye safety requirements.

The new lidar, initially ground tested during MERMOZ II field study, was installed on the CV580 during CFDE III and will be used in FIRE III. The Canadian participation for FIRE III is planned for April 1998 during the spring transition period when water and mixed phase clouds begin to appear. Since clouds cover 40% to 60% of the skies over the Arctic Ocean, they exert a large influence on the radiation balance in the Arctic.

FIRE III involves four aircraft which are staggered in time to cover a significant portion of the Arctic spring and early summer. The Canadian field study will be based in Inuvik, Northwest Territories. Several flights will be over the Surface Heat Budget of the Ocean (SHEBA) site to support ground-based measurements from the ice camp. A Canadian Coast Guard icebreaker, the Des Grosseillers, was frozen into the ice pack in Fall 1997. The lidar, with depolarization capabilities, will be able to identify arctic haze and ice crystal layers. A ground-based lidar is aboard the icebreaker and will provide a useful comparison with the airborne system. The high vertical and horizontal resolution of the lidar will be an asset in meeting the objectives of FIRE III.

2.2 HAZARDOUS AIR POLLUTANTS

2.2.1 IADN Program Overview

[R. M. Hoff]

Under Annex 15 of the Great Lakes Air Quality Agreement (1987), the governments of Canada and the United States are tasked with undertaking research and surveillance, and monitoring of priority toxic chemicals being atmospherically deposited to the lakes. As part of that Annex, the Integrated Atmospheric Deposition Network (IADN) was established.

IADN entered its 7th full year of operation under the First Implementation Plan (IP1). Since this plan expired in 1996, future requirements for the IADN program have been assessed. The IADN Scientific Steering Committee organized a Peer Review Panel (November 1997) to assess the productivity of the first six years of the IADN program against the stated goals of IP1. The Peer Review Panel and their expertise were: Michael Oehme, U. Basle (organic chemical analysis); Michael Hoffman, CalTech (atmospheric chemistry); Derek Muir, NWRI (organic chemical impacts on wildlife); Hans van Jaarsveld, RIVM, Holland (toxic chemical transport and modelling); Philip Hopke, Clarkson University (trace elements). Steve Eisenreich, Rutgers University (trace organic movement in the Great Lakes) served as a Resource Person to the Panel.

A report "Technical Report of Progress under the Integrated Atmospheric Deposition Network 1990-1996" was prepared for their review. This report surveys the history, mandates, current status, delivery, and future needs seen for the program. The Technical Summary suggested that IADN continue for another six-year period, but undergo some changes. The Peer Review Panel report was favourable and made some important recommendations. The IADN Steering Committee responded to these and prepared a draft second Implementation Plan (IP2) to which the stakeholders will respond.

2.2.2 IADN Data Analyses

[R. M. Hoff, K. Brice, C. Audette, J. Woods, F. Froude, B. Martin]

All AES metals and PAH data through 1995 is now processed through RDMQ (see 1.5.3) and data up to the end of 1994 has been passed on to NAtChem/Particles. Data from the Ecosystem Health Division (C.H.Chan), the National Water Research Institute (W. M. J. Strachan), the Illinois State Water Survey (C. Sweet) and the Indiana University (R. A. Hites) have been put into RDMQ.

A paper on the atmospheric trends in air and precipitation concentrations has been published. Loading estimates of the amounts of these chemicals coming from the atmosphere to the lakes and volatilizing from the lakes have been made every two years during the program.

IADN data have also been interpreted in terms of air trajectory analyses and other statistical tests which give information on source-receptor identification. These techniques identify many of the semi-volatile organic compounds (SVOCs) as potentially coming from outside the Great Lakes basin, while some of the anthropogenically-released substances, such as the PAHs and trace elements, have in-basin sources.

2.2.3 Smog Chamber Studies

[D.A. Lane, N.J. Bunce (University of Guelph), S.J. Townsend (GENEXUS Inc.), S.S. Fielder (University of Central Queensland, Australia)]

One of the objectives of these studies is to advance the knowledge of the gas phase reactions of various Polycyclic Aromatic Compounds (PACs), and other gas phase compounds, with the OH radical. The other is to provide this information to those at AES who are creating and implementing models on the long-range transport of hazardous air pollutants in the atmosphere.

Studies of the reaction of naphthalene were continued with the objective of determining the pathways of the reactions that produce the products that we detect. Collaboration with Dr. N. Bunce and his graduate students at the University of Guelph was vital to the success of the work. The work also enlisted the services of Dr. Stanley Townsend of Genexus Inc. and Dr. Scott Fielder of the University of Central Queensland, Australia, who have developed the Graphic Electronic States Molecular Modeling (GESMM) program which assesses the nature of atmospheric chemical reactions through the use of quantum

chemical computations. In the past year, the term GESMM has been changed to a more descriptive phrase: Frontier Molecular Orbital (FMO) Mapping. The AES super computer at Dorval has run the FMO mapping program in an attempt to identify all of the products that one might expect to find from the reaction of naphthalene with the OH radical.

In addition to the identification of those products, the computational methods have suggested that singlet delta molecular oxygen ($^1\Delta_g)O_2$ is likely to be a strong contender for the OH radical in the reactions in our smog chamber. Several products, which may not be produced by the reaction with the OH radical, have been postulated.

2.2.4 Denuder Development

[D.A. Lane, Dr. L. Gundel (Lawrence Berkeley National Laboratory)]

This program advances the diffusion denuder technology for the determination of the gas and particle partition ratios for airborne Polycyclic Aromatic Compounds (PACs) and Organochlorines (OCs) that are classified as endocrine disrupters. This work provides the Great Lakes research program with information on the atmospheric partitioning of these compounds as a function of temperature and relative humidity.

In collaboration with Dr. Gundel, the technology of the GAP sampler (developed at AES) has been merged with that of the IOVPS (developed at LBNL). The resulting instrument (Integrated Organic Gas and Particle Sampler, IOGAPS) is now commercially available.

To characterize the efficiency of particle transport through the denuder as a function of particle size, measurements were made with an optical particle counter through both coated and un-coated denuders. Denuders were coated and XAD resin adsorbent was prepared, enabling air sample measurements to be taken at Point Petre during February 1998. The denuders, filters and adsorbers were sealed and shipped to Berkeley CA for analysis. The samples were analyzed by an HPLC/dual fluorescence detector method developed by Dr. Gundel for the analysis of Environmental Tobacco Smoke extracts. The method sensitivity was vital for the samples.

2.2.5 Atmospheric Particulate-Phase Mercury

[J. Lu, B. Schroeder, A. Steffen]

The objectives have been to develop, evaluate and apply a viable procedure for the sampling and analysis of total particulate-phase mercury (TPM) existing in ambient air.

Since it frequently accounts for only a few percent by mass of the total mercury occurring in ambient air, mercury in the particulate phase is one of the most difficult forms of mercury to determine accurately. Yet its determination is critical in understanding the cycling of this element in the environment because, relative to elemental mercury vapor, mercury-containing particulates in air are readily deposited to the earth's surface through rain-out and wash-out processes, as well as by dry deposition mechanisms. Although effectively collecting and accurately analyzing particulate-phase mercury without artifacts is now feasible, it usually requires ultra-clean techniques/reagents and a clean room facility, and the analysis procedure is usually time-consuming.

The new technique combines the advantageous features of several currently used techniques and promises to be a precise, accurate, fast and cost-effective technique for sampling and analysis of TPM in ambient air. The improved device is validated by using a standard reference material and by field intercomparison studies. The technique has been applied in the Arctic for sampling and analysis of particulate-phase mercury.

A nickel screen has replaced the Teflon screen, eliminating the loading/unloading steps after sampler cleaning and before sample analysis, and reducing further contamination risk. The improved device has been validated using an alternate standard reference material (SRM 1633b, NIST), for which a certified value for mercury exists. The determined value and the certified value agree well (relative error < 3 % - 2% lower than that obtained using the previous version of the device).

The new technique was applied at Alert in April 1997. Particulate mercury concentrations ranged from <2 to 449 $pg.m^{-3}$. Comparison of the values with total gaseous mercury (TGM) and ozone (O_3) concentrations, measured at the same time and at the same location, reveals that particulate mercury concentrations in ground-level air increase when TGM and O_3 concentrations are depleted. In some cases, values are much higher than those of the TGM concentrations that occur during springtime depletion episodes. These results provide experimental evidence that gaseous elemental mercury is transformed into one or more oxidized forms, which are less volatile and, hence, more likely to be attached to particulate matter in air.

This technique was compared with procedures used by NILU (glass fiber filters for sampling and acid extraction for sample preparation) and IVL (Teflon filters for sampling and acid extraction for sample preparation) in June 1997 at Ny-Ålesund, Spitsbergen. When there was no ozone depletion, maximum differences between the results obtained using the new technique and those obtained by NILU and IVL were less than 2 and 3 times, respectively. This compared with differences reported in literature, i.e., a factor of 10 between quartz wool plugs and filter packs; a factor of ~23 between the denuder technique and a filter pack; > 4 times between Teflon filter pack and quartz fiber filter pack. When there was a major ozone depletion event, the values of TPM concentrations obtained using the method developed in this work were elevated. A situation similar to that observed at Alert in April 1997, further confirming the occurrence of a transformation of gaseous mercury in the Arctic after polar sunrise.

The field intercomparison study with the University of Michigan (G. Keeler) was carried out in Ann Arbor, MI, in March 1998. The concentrations of particulate-phase mercury obtained by AES ranged from 1.2 to 32 $pg.m^{-3}$. Results from Dr. Keeler for this study are not yet available. The field intercomparison study with the University of Connecticut (W. Fitzgerald) started in February 1998 at Alert and will continue through the Polar Sunrise Experiment (PSE)-98.

2.2.6 Atmospheric Mercury at Alert

[W. Schroeder, A. Steffen, V. Hudec, L. Barrie]

Data were obtained on "background" ambient air concentrations for total gaseous mercury (TGM) at Alert in order to determine and define:

- current baseline concentrations of TGM in the Canadian High Arctic;
- temporal variability and global trends of atmospheric mercury concentrations;
- reason for dramatic springtime depletions in TGM concentrations at Alert, and presumably other Arctic/Antarctic locations;
- locations/regions of major emission sources for the mercury which is detected at Alert;
- significance of long-range atmospheric transport and deposition of this priority heavy metal to Arctic ecosystems.

The Arctic ecosystem continues to exhibit increasingly disturbing evidence of contamination by persistent toxic substances, including metals such as mercury. Mercury is of concern owing to its pervasive presence, its inherent toxicity (especially in the form of methyl-mercury) and its ability to be greatly bio-magnified in the Arctic food web. Because of its unique physical/chemical properties, elemental mercury

vapour is estimated to have a mean global residence time of 6 months to a year, thus capable of long-range atmospheric transport. Accordingly, the atmosphere is believed to be a major pathway for introduction of mercury into the Arctic environment.

The high-temporal resolution, ground-level atmospheric measurements of total gaseous mercury (TGM) were continued Alert with an automated Tekran mercury vapour analyzer. During the spring of 1997, following polar sunrise, once more the intermittent occurrence of mercury vapour depletion events in ambient air at Alert was observed. As noted before, the TGM pattern strongly resembles that of surface ozone that also exhibits dramatic depletion events following polar sunrise. Based on this experience, a standard operating procedures manual for total gaseous mercury measurements was prepared.

2.2.7 Lake Superior Mercury Measurements

[S. Steffen, B. Schroeder, T. Berg, G. Lawson, B. Strachan (NWRI)]

Mercury is easily dispersed (from both natural or anthropogenic sources) in the environment and its persistence makes it a good candidate for long range transport and deposition. The Great Lakes are susceptible to such deposition because of their proximity to various urban and industrial areas. The International Joint Commission has identified Lake Superior as being at risk due to the presence of persistent toxic chemicals, thus investigations into the mercury loadings were undertaken. Shipboard measurements on the CSS Limnos were taken during 2 expeditions (August 1996 and May 1997) using the Tekran mercury vapor analyzer to obtain total gaseous mercury (TGM) concentrations over Lake Superior, in conjunction with measurements for other persistent organic pollutants. As well, testing of a prototype set-up and measurements were also undertaken to analyze dissolved gaseous mercury in the lake water in a collaborative effort with Greg Lawson of National Water Research Institute.

The ship traveled from Sarnia through Lake Huron to Lake Superior on both occasions. The mercury analyzer was operated at five minute integrated sampling intervals for 24 hours a day. The TGM concentrations measured during August 1996 were quite constant (and consistent with expected values), ranging from approximately 1.9-2.5 $ng.m^{-3}$ and averaging 2.23 $ng.m^{-3}$. During the 1997 expedition, 2 analyzers were run in parallel on 5-minute cycles. The three hour averaged concentrations ranged between 1.47 and 1.77 $ng.m^{-3}$ and the overall average concentration was found to be 1.64 $ng.m^{-3}$. The concentrations from the springtime study were found to be 35% lower than those measured during the summer of 1996.

There appears to be no diurnal variation in the daily samples for either expedition. As well, there is no daily correlation between the increase in air and water temperatures, and TGM concentrations. However, there is an overall correlation in the TGM concentrations and air temperatures between the 2 years. Temperatures were found to be significantly different for both years. The average water temperature in 1997 for the lake perimeter was 3.5 °C, whereas for mid-lake it was 2.2 °C. Air temperatures ranged from 0 to 11.4 °C. In 1996 the water temperature averaged 11.6 °C for the lake perimeter, with 5.6 °C in mid-lake. Air temperatures ranged from 7.4 to 23.5 °C. There were slightly higher TGM concentrations in the mid-west and southwest lake areas (approximately 5% higher than the mean) and slightly lower concentration in the east and southeast lake area (approximately 5% lower than the mean).

Careful inspection of the ship's influence was undertaken in 1997 because of the mercury spill of 1996. It was found that while the ship was on station, there was little to no increase in the mercury concentrations. When on station the ship's bow is expected to face the wind so that the effect of the ship is minimised on the air and water samples taken. It was determined that the ship had a negligible effect on the air measurements.

On the 1996 expedition, preliminary testing of a dissolved gaseous mercury (DGM) sampling and analysis system was performed and was applied on the 1997 cruise. Samples were collected in a 4L Go-Flo bottle and transferred to a 1L Teflon bottle. Samples were sparged with UHP argon to release the DGM from the water samples. The purged air stream was fed through an in-line Nafion drying tube (to reduce moisture from the sample air) and then into a Tekran mercury vapour analyzer for analysis and detection. During the 1996 study, preliminary DGM concentrations for 0-5 m and sub-5 m depths were 25.2 and 29.9 $pg.L^{-1}$, respectively. During the 1997 expedition, more water samples were evaluated and gave an average concentration of 27.9 $pg.L^{-1}$ for depths of 0-5m and 32.9 $pg.L^{-1}$ in the sub-5 m depths. From these studies calculations into the air-water exchange of mercury in Lake Superior will be undertaken once all water analyses are completed.

2.2.8 Air-Soil Exchange of Mercury

[W. Schroeder, A. Steffen, G. Edwards (University of Guelph), P. Rasmussen (Geological Survey of Canada), G. Eiras, D. Schneeberger (Tekran Inc.)]

Development continued on two complementary flux measurement methods (micrometeorological gradient, and dynamic flux chamber methodology interfaced with a Tekran mercury vapour analyzer) for continuous determination of air-surface exchange fluxes of volatile mercury species. Field studies were conducted to measure mercury air-soil exchange fluxes under a variety of environmental conditions. In addition, evaluations were made of rugged, portable equipment and methodology for measuring mercury fluxes.

Two complementary methods for determining fluxes of trace atmospheric gases, including volatile mercury species, over soil (or water) surfaces are in current use: enclosure-based methods and micrometeorological (gradient) methods. During the summer 1997, two major mercury flux measurement field studies were carried out - one near Thunder Bay, Ontario, and the other, an international flux measurement methods intercomparison study (*Desert STORMS 1997*), near Reno, Nevada. For the field study conducted in the vicinity of Thunder Bay, Ontario, the first site investigated was at Kakabeka Falls where mercury fluxes were measured (for the first time ever) over a granite surface. This location was selected as a background site since the local granite contains a very low concentration of mercury. The second site was the Klages Road quarry which contains black shale with elevated levels of mercury (up to ~ 2 ppm). As expected, the granite site (Kakabeka Falls) gave daily averaged flux values close to zero $ng/m^2/h$. The Klages Road quarry site produced daily averaged flux values of 10 ± 1 $ng/m^2/h$. At each flux measurement site samples of substrate were collected and will be analyzed for their mercury content by the Geological Survey of Canada.

The Steamboat Springs geothermal area near Reno was selected for the mercury flux measurement methods field intercomparison study (September 1997) sponsored by the Electric Power Research Institute. During the study, daily averaged mercury fluxes were 9.7 ± 5.6 $ng/m^2/h$, with positive fluxes (emissions) measured during daytime hours and negative fluxes during nighttime, indicating deposition of mercury to the soil surface.

2.2.9 Hazardous Air Pollutants

[Y-F Li, T, Bidleman, L. Barrie]

The purpose is to compile information and create a computerized database of historical, present, and predicted global usage/emissions of the persistent organic pesticides with 1°x1° lat/long resolution. In particular, global emissions trend information is needed to interpret seasonal and long-term trends of organochlorines in air, water and the food chain, which will be examined in "integrated" projects being proposed to the Northern Contaminants Program.

This project also contributes to the United Nations Economic Council of Europe's Task Force on Persistent Organic Pollutants and Heavy Metals; the UN ECE Expert Panel on Emissions; the Global Emissions Inventory Activity of the International Geosphere/Biosphere Program; and the United Nations Environment Programme (UNEP). Direct connections between worldwide usage of HCH and the air concentration of HCH in the Arctic is clearly identified in Figure 1.

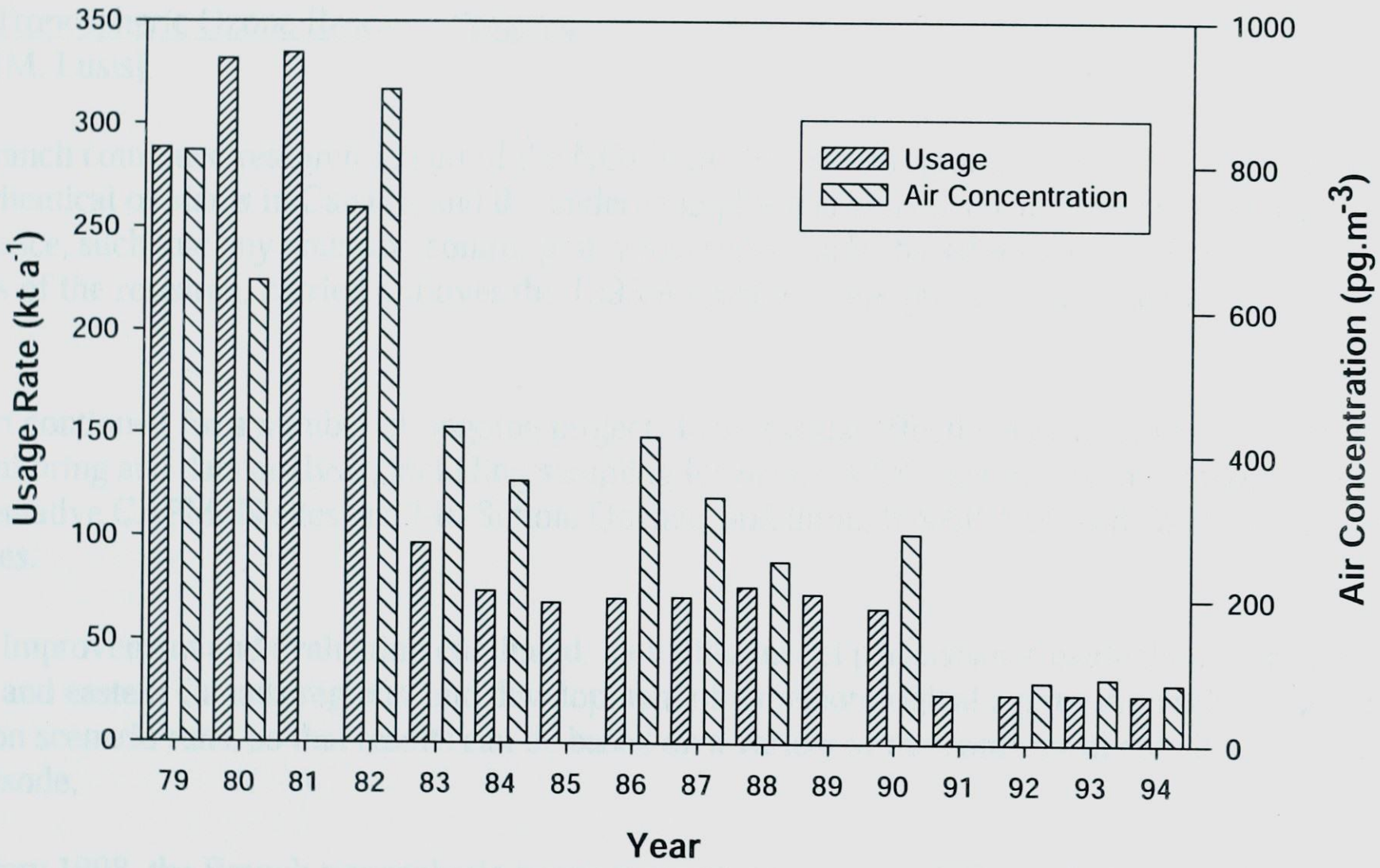

Figure 1: Long-term trends of global Technical HCH usage and mean air concentrations of α-HCH in the arctic regions from 1979 to 1994 (Li et al. 1998a)

The first joint project with the Nanjing Institute of Environment Science, the People's Republic of China, compiling the historical trends of chlorinated pesticide in China, has been completed, and the results will be published soon. The second joint project with Hong Kong University and the Nanjing Institute of Environment Science that looks at the pesticide exposure risk zone classification in the Taihu Lake Basin, China, which started last year, has been made good progress. Both of these two projects were partially funded by UNEP.

A gridded database of monthly atmospheric emissions of HCH isomers for 1990 is in the final stage. This work contributed to the identification of sources of Canadian Arctic contaminants.

2.2.10 NAtChem/Particle-Toxics Data Base
[R. Vet, C.U. Ro, B. Sukloff, D. Ord, P. Liu]

The National Atmospheric Chemistry Data Base (NAtChem) activity for Particulate Matter and Toxics data focused on several initiatives: evaluation and selection of candidate networks; data standardization; data evaluation of selected networks; data quality control and input; prototype statistical summaries and maps; web site development; and publication of analysis results. Over 20 major monitoring programs have been identified in North America and 11 networks' data have been loaded into the database. The data have undergone an initial analysis and the results were included in a conference paper.

2.3 TROPOSPHERIC OZONE

2.3.1 Tropospheric Ozone Research Program
[M. Lusis]

The Branch continued research as part of the NOx/VOC Science Program. The goal is to characterise photochemical oxidants in Canada, and the underlying physical and chemical processes that control their occurrence, such that any emission control policy measures can be based on sound scientific information. Results of the research, carried out over the 1993/96 period, were published as Assessment Reports in 1997.

Support continued for a number of ongoing projects to assess the effectiveness of emission controls through air monitoring and data analysis, including sampling for ozone, VOCs and nitrogen compounds at regionally representative CAPMoN sites and Mt. Sutton, Quebec, and through NAtChem and Oxidants database activities.

Model improvement and evaluation continued, including model performance evaluation in the Lower Fraser Valley and eastern Canada regions, and development of a meteorological aggregation scheme for conducting emission scenario runs, so that results can be based on a variety of meteorological conditions rather than just one episode.

In January 1998, the Branch tropospheric ozone research program (or NOx/VOC Science Program) was merged with the Acidifying Emissions research program. There are several strategic reasons for this combination, but there is a sound scientific reason as well. The oxidizing capacity of the atmosphere, which was the focus of the NOx/VOC science plan, is also central in determining the production of acidifying material.

2.3.2 CAPMoN Ozone/NOx Measurements
[D. MacTavish, N. Lance, R. Braga, B. Kessler, C. Brunski, W. Kobelka, D. Ord, EC Regional Inspectors]

CAPMoN (Canadian Air and Precipitation Monitoring Network) continues to support the NOx/VOC (Nitrogen Oxides/Volatile Organic Compounds) Program through its daily air filter and precipitation measurement programs by determining concentrations of nitrogen compounds in air and precipitation samples. EC Regional staff maintained the majority of on-site field operations.

Continuous ozone measurements were made at 8 of CAPMoN's monitoring sites. The ozone measurements at Chalk River, Ontario, were discontinued in April 1997. Bratt's Lake, Saskatchewan,

was added as a ground-level ozone site as a cooperative effort between CAPMoN and the Baseline Surface Radiation Network.

Quarterly inspections/calibrations were performed at all ozone measurement sites. This year marked the fourth year of an intensive ozone audit program designed to ensure the accuracy and quality of CAPMoN's ozone data. Zero level QC (ZeroQCnet) of CAPMoN ozone, air filter and NOy data transferred by telemetry was reviewed, expanded and further automated. CAPMoN and Regional staff are now able to access and review site specific data and graphs via the Intranet.

2.3.3 Ozone Forecasting

[J. Pudykiewicz]

In order to aid in the timely forecasting of tropospheric ozone concentrations, a revised version of the chemical reaction solver used in the AES CTM developed by P. Makar in 1996 was installed in the place of the old ADOM solver. The new solver reduced the time required to produce an ozone forecast by a factor of twelve, while providing identical results to the previous version. The new code made the use of the CTM for ozone forecasting possible by reducing the processing time to within operational requirements set by the Canadian Meteorological Centre.

2.3.4 Box Modelling of NOx and VOCs

[T. Dann (River Road Lab), D. Albin (MYDA Consulting), S.M. Li, J. Bottenheim]

The National Air Pollution Surveillance (NAPS) network data were sorted by extracting records for which O_3, NOx and VOC measurements were time-coincident. The VOC species were lumped into the hydrocarbon species of the new AES oxidant mechanism, and the results were used as the initial conditions for a series of box model sensitivity runs to determine ozone sensitivities to changes in VOC and NO concentrations, in order to determine emission reduction strategies. The regions with the highest ozone concentrations (southern Ontario and the Lower Fraser Valley) were found to be "VOC limited" (reductions in NO would have no effect or an adverse effect on ozone concentrations). For one-hour forward integrations, internally bonded alkenes were found to have the biggest effect on ozone mixing ratios, followed by higher aromatic compounds such as the xylenes and trimethylbenzenes.

2.3.5 MERMOZ II

[J. Mailot, J.W. Strapp, K.B. Strawbridge, N. Donaldson, A. Walker, I. MacPherson, M. Benjamin, S. Belair, L. Poissant, C.M Banic]

MERMOZ (Montreal Experiment on Regional Mixing and Ozone) II undertook to compare actual measurements of the summer turbulent boundary layer in the Montreal area to calculations from the MC-2 model. The Twin Otter aircraft (National Research Council of Canada) performed flux measurements in a 25-km box using several different flight plans depending on atmospheric conditions and wind direction. Part of the experiment involved flying over a network of soil moisture probes and precipitation gauges with airborne microwave radiometers. A ground site located at St. Polycarpe, Quebec, had several instruments running for a two-week period. Among these were a ground-based lidar, 915 MHz wind profiler, 10 m and 3 m meteorological towers, 2-m flux tower, time-lapse cloud video camera, and mercury measurements.

The field study provided an excellent opportunity to ground test the new airborne lidar data acquisition system and marine radar (required for eye-safety considerations during scanning lidar applications) for

sensitivity to small aircraft targets. Even with a significant amount of ground clutter aircraft were detected. It was determined that automating the radar to activate the laser shutter would be difficult in locations with significant ground clutter.

Two days were selected as good cases to compare with the MC2 model. The lidar performed very well in measuring boundary layer growth throughout the day. Comparisons are underway between the lidar and the wind profiler in determination of boundary layer height. Various algorithms are being developed to automate boundary layer height determination from the raw lidar data.

2.4 STRATOSPHERIC OZONE

2.4.1 Stratospheric Ozone and UV-B
[J.B. Kerr]

Measurements of stratospheric ozone and global UV-B irradiance continued at the ground-based sites in the Canadian ozone network. Total ozone, Umkehr and global UV-B irradiance measurements were made at twelve sites with Brewer spectrophotometers and vertical profile ozone measurements were made at six sites with ozonesondes. There are two main objectives of these systematic measurements. The first is to detect, quantify and evaluate long-term changes that are occurring in stratospheric ozone and UV-B irradiance. The second is to provide near real-time information for the general public regarding the state of the ozone layer, levels of UV radiation and forecasts of UV radiation.

The Branch operates the WMO Brewer Calibration Centre at the Downsview site that provides the primary reference for Brewer total ozone measurements. It consists of three instruments (triad) which are independently calibrated on an absolute scale. Part of the instrument calibration is the measurement of extraterrestrial constants determined by the Langley method under stable observing conditions at Mauna Loa Observatory (MLO) in Hawaii. One of the triad members (Brewer instrument #14) was calibrated at MLO in April 1997. In addition, two Brewer instruments (one single and one double monochromator) were installed at MLO to operate on a permanent basis under remote control from Downsview.

The weekly ozonesonde measurements were augmented at the Arctic sites with additional sonde flights in support of the European MATCH campaign and for the observing program at the Eureka observatory. Analysis of the data records from the Canadian ozone/UV-B network has continued. Results were presented in a special assessment entitled "Ozone Science: A Canadian Perspective on the Changing Ozone Layer" which was prepared for the Meeting recognizing the tenth anniversary of the Montreal Protocol. The data have also made an important contribution to the next International Scientific Assessment of Ozone Depletion (1998). Results of low ozone values observed over the Arctic during the previous winter (1996/97) were published in a special edition of GRL (November 1997).

2.4.2 Arctic Stratospheric Ozone
[H. Fast]

The Eureka observatory was established in order to advance our understanding of stratospheric ozone chemistry, to monitor ozone depletion in the Arctic and to investigate the effect of this depletion on lower latitude regions. Towards this goal the Experimental Studies Division, in collaboration with national, Japanese and U.S. institutions, carried out another winter campaign at Eureka.

The winter campaign started in September with the recording of solar absorption spectra using the Bomem DA8 Fourier transform infrared (FTIR) spectrometer whenever the sun was visible. The University of Denver automated FTIR system recorded atmospheric emission spectra throughout the winter. The data from both FTIR instruments will yield information on the concentration of many gases above Eureka, which are essential for the analysis of ozone chemistry in the Arctic.

The ozone lidar was operated by CRESTech for most of the nights from November to March to obtain high-altitude ozone and temperature profiles. The aerosol lidar, for measuring polar stratospheric clouds (PSC) as well as background aerosol in the troposphere and stratosphere, was used by Japanese scientists from the MRI, CRL and the University of Nagoya.

The modified Brewer ozone spectrophotometer, which is capable of using the visible as well as the conventional UV ozone bands, was set up so as to be able to download the data from AES headquarters during its unattended operation on the roof of the observatory.

Ozonesondes were launched from Eureka in support of the various measurements at the observatory and in collaboration with the European Match ozonesonde campaign which also involved the other five Canadian ozonesonde stations. Japanese scientists from the JWA supported a two-week radiosonde program to study atmospheric gravity waves.

Data analysis of this winter's measurements is expected to be interesting in view of the unusually warm atmosphere over Eureka which prevented PSCs forming in contrast to the previous winter when PSC observations were frequent and persisted well into March.

2.4.3 Ground-based FTIR Measurements

[H. Fast]

High-resolution solar absorption spectra were recorded approximately twice per month at CARE, using the Bomem DA8 FTIR spectrometer, in order to continue the monitoring of atmospheric gases implicated in stratospheric ozone depletion and the enhanced greenhouse effect. Observations made at CARE will be used for validation of the space-based MOPITT (Measurements of Pollutants In The Troposphere) carbon monoxide and methane measurements.

2.4.4 WOUDC Activities

[E.W. Hare, D.I. Wardle, J.B. Kerr]

The World Ozone and Ultraviolet Radiation Data Centre (WOUDC) has two component parts: the World Ozone Data Centre (WODC) and the World Ultraviolet Radiation Data Centre (WUDC).

The WODC processes, archives and publishes world ozone data reported by over 300 stations. These data have been traditionally published bi-monthly in the "Ozone Data for the World" red book along with an annual catalogue which details all the data received each year. However, beginning with the 1996 data sets, the red book is now published semi-annually along with the annual catalogue. The data archive is comprised of total column ozone, surface ozone, vertical profile data (derived from lidar, ozonesonde and Umkehr techniques) and spectral UV data sets.

The WOUDC has provided data by means of the Internet since January 1995. Approximately 80% of the data submitted to the WOUDC are transmitted electronically, by means of either email or ftp. Personal ftp

accounts are created for individual agencies or data originators for data submission and this new approach to data submission has increased the turn around time for posting data sets on the Internet. Data are now posted monthly instead of the traditional bi-monthly schedule. Development has begun on a new data submission format called the extended Comma Separated Values (or extCSV) that will provide the data originator with more freedom to submit higher spatial and temporal resolution data. The WOUDC web site underwent several changes, mostly to organize the data submission and retrieval information.

2.4.5 Space and Aircraft Experiments

[C.T. McElroy, C. Midwinter, R.B. Hall, S. Werchohlad, D.V. Barton, J. Davies]

The space experiments section participated in the 1997 POLARIS (Polar Ozone Loss in the Arctic Region in Summer) project operated out of Fairbanks, Alaska, using the NASA ER-2 high-altitude research aircraft. The project comprised three field excursions, two in the late spring-early summer and one in the fall, of approximately three weeks duration each. The purpose of the experiment was to investigate the significance of various chemical loss processes in closing the ozone budget in the Arctic during the summer.

The major AES contribution to the project is the Experimental Studies Division's Composition and Photodissociative Flux Measurement (CPFM) experiment. The CPFM instrument is an UV-visible spectrometer that is used to determine the radiative environment of the ER-2, enabling accurate estimates of the rates of photochemical reactions to be made. A Brewer Ozone Spectrophotometer was also operated by AES at Fort Wainwright in Fairbanks between April and September of 1997 to provide ozone column data in support of the POLARIS project. The CPFM instrument makes direct measurements of several components of the radiation field in the vicinity of the ER-2, as well as the determining the wavelength-dependent, apparent albedo below the aircraft, and the column amount of ozone above.

Considerable time was spent in developing analysis software for reducing radiometric data and for spectral fitting. Improved codes were developed to provide data with better signal-to-noise ratio using full-spectrum fitting rather that the Brewer ratio technique. The new analysis codes produce improved-quality ozone measurements and make it possible to measure trace gases with smaller atmospheric optical depths.

Two proposals were developed in response to the NASA ESSP (Earth System Science Pathfinder) Announcement of Opportunity. One of these involved developing a new spectrometer based on the CPFM instrument to be included on a satellite carrying an FTIR (Fourier Transform Infrared) spectrometer in a joint project with the Jet Propulsion Laboratory. The second proposal was made by the Johns Hopkins Applied Physics Laboratory and would have coupled an AES-designed UV-visible spectrometer, used to measure ozone in the backscatter mode, with a Fabry-Perot interferometer proposed by the University of Michigan. Unfortunately, neither of the proposals was selected for flight, although the AES/JPL proposal was rated as the top for science and designated as the first alternate mission in the first round of ESSP selections. It was decided to propose it again for the second round Announcement of Opportunity.

2.4.6 MODE Experiment

[D.W. Tarasick, W. Ward (CRESTech), W. Gault (York), C.T. McElroy, K. Gilbert (UWO), P. Gauthier, G. Klaassen (York), W. Hocking (UWO), A. Manson (U. Sask), G.G. Shepherd (York)]

The MODE (Middle Atmosphere Ozone, Dynamics and Energetics) Experiment is a small satellite payload proposed in 1997-98 for the first mission of the Canadian Science Satellite (SCISAT1) program. It consists of three small instruments:

- Mesospheric Imaging Michelson Interferometer (MIMI): A near-IR field-widened Doppler imaging Michelson interferometer, based on the WINDII instrument on UARS. It will use six lines in the $O_2(^1D)$ band at 1.27 microns on the limb to measure winds, temperatures and ozone concentrations globally from 45 to 100 km altitude. The data will be unique, as wind measurements at this altitude have never been made from space.
- Ozone Backscatter Observation Experiment (OBOE): A development of the AES SunPhotoSpectrometer that has flown on the U.S. Space Shuttle and aboard the NASA ER-2 high-altitude research aircraft. OBOE will make measurements of total column ozone and its vertical distribution via backscattered UV and visible radiation. It will measure NO_2, stratospheric aerosols, and other species important to ozone chemistry, such as BrO (which it detected in the arctic troposphere in spring) and PSCs.
- Mesopause Oxygen Imager (MOXI): A nadir-pointing CCD imager with the prime purpose of measuring small spatial scale intensity fluctuations (gravity waves) in the $O_2(^1S)$ band airglow. This imager will enable studies of the characteristics, sources and climatology of this important middle-atmosphere energy transport mechanism.

The experiment also includes extensive ground-based observations and the assimilation of these and meteorological data to produce a global data set from the ground to 100 km. MODE received Phase A funding during 1998 but was not selected for SCISAT1. Currently funding is being provided by CSA to develop the instruments further while launch opportunities are sought. AES interest in MODE was quite strong, particularly because of the OBOE ozone measurements, but also because of the mesospheric wind and ozone measurements from MIMI, which would be very valuable to the CMAM and MAI projects. The gravity wave data would also be valuable to CMAM.

2.4.7 Middle Atmosphere Initiative

[D.W. Tarasick, G. Brunet, S. Pellerin, N. Ek, S. Edouard, P.-A. Michelangeli, Y. Rochon, P. Gauthier]

Currently the Middle Atmosphere Initiative (MAI) comprises two main projects. The first focuses on improving long-range forecasting through the assimilation of ozone data in real time using the new operational global forecast model, GEM, and the 3DVAR system. This project has produced some results, using TOVS total ozone retrievals that appear reasonable. Comparison with TOMS, Brewer and ozonesonde data is underway.

The second addresses the understanding of the circulation of the stratosphere and lower mesosphere, in order to understand better ozone change (particularly transport) and climate change problems, and will be researched through the assimilation of at least one year of data from the UARS satellite, using the CMAM. Initial experiments using the 3DVAR system with the CMAM are in progress, including the calculation of background error covariances. Assimilation experiments with MLS temperature retrievals have begun as well (initially using GEM).

2.5 CLIMATE CHANGE

2.5.1 Climate/Global Warming Program

[K. Higuchi]

The overall objective of the Branch's Climate program is to contribute to our understanding of greenhouse gases and aerosols - their trends, budgets and role in climate change - by carrying out measurements, modelling and process studies with a Canadian focus, and by interfacing with other major international programs.

The objectives of the measurement program are:

- to obtain, for the various regions of Canada, background concentration levels of greenhouse gases and other atmospheric constituents, their variability and possible long-term changes;
- to evaluate the global transport and transformation of climatically-active trace species in the Canadian context, and identify their source regions and major sinks;
- to determine the impact of emission control strategies for specific components such as freons and carbon dioxide;
- to support the WMO Global Atmosphere Watch Program by submitting data to the appropriate WMO Data Centre.

To meet these objectives, resources were directed toward the ongoing measurement activities at Alert, and the two coastal sites (Sable Island and Estevan Point). At these sites, some or all of the following measurements are made: CO_2, CH_4, N_2O, O_3, PAN, CO, CFCs, Radon, C and O stable isotopes in CO_2 and CH_4, aerosol scattering and chemistry, PAHs, hydrocarbons, and meteorological parameters. In 1997, the Branch's stable isotope laboratory commenced routine analysis for C and O isotopes in atmospheric flask samples of CO_2 and CH_4 that were collected at Alert and Estevan Point.

Due to changed priorities, operations at the Fraserdale station had been shut down in the fall of 1996. Starting in the spring of 1998, a sampling program was resumed, as part of a larger project co-funded by PERD, to address the role of the Canadian Boreal Forest as a sink for atmospheric CO_2. It is expected that this project will be closely co-ordinated with related measurements now underway as part of BERMS (Boreal Ecosystem Research and Monitoring Sites), a follow-up to the Canadian-USA collaborative BOREAS study.

Canadian support continued for implementing the Chinese GAW station at Waliguan Mountain - a co-operative project that will provide, for the first time, background levels of aerosol chemistry and other atmospheric constituents from a remote Asian continental site.

Modelling of aerosols and their impact on climate continued with the support of the PERD program and as part of the Canadian Climate Research Network. The objective of this ongoing work is to assess the influence of anthropogenic sulphate and black carbon aerosols on northern hemispheric climate, in particular the Canadian climate in particular, by developing a high resolution northern aerosol regional climate model (NARCM) with anthropogenic aerosols as active constituents.

An international panel of peers reviewed the Canadian Baseline Program in May 1997. This was the second such review - the first one took place in 1991. The Panel submitted its report February 1998, and copies are available from the program manager Maris Lusis.

2.5.2 Modelling of Canopy Emissions

[Jose Fuentes (U. of Virginia), D. Wang (River Road Lab), R. Staebler, A. Wiebe]

A one-dimensional canopy model was constructed to simulate the emissions and chemistry of biogenic hydrocarbons during the summer of 1995 at Borden, Ontario. The main findings of the study were:

- an improved diffusion parameterization greatly improves the accuracy of isoprene simulations compared to previous work.
- the commonly used assumption of "no chemical losses" in emission flux measurements may underestimate emission rates of biogenic hydrocarbons by as much as 40%.
- substantial formation of HOx due to the reaction of ozone with biogenic and anthropogenic hydrocarbons occurs at night and in the early evening and morning hours under the canopy.
- organic peroxide formation due to reactions between biogenically derived organic peroxide radicals and HO_2 is substantial in NOx limited environments such as Borden.
- due to the very low NOx levels, local ozone formation from biogenics was found to be minimal.

AIR QUALITY RESEARCH BRANCH

PUBLICATIONS 1997/98

JOURNAL PUBLICATIONS 1997/98

Biegalski, S. R., S. Landsberger and **R. M. Hoff** 1998: "Source-receptor modeling using trace metals in aerosols collected at three rural Canadian Great Lakes sampling stations", J. Air & Waste Manage. Assoc., 48, p.174-184.

Biegalski, S.R., S. Landsberger and **R. Hoff** 1997: "High bromine aerosol concentrations near Lake Huron from long-range transport from the Arctic during Polar Sunrise", J. Geophys. Res. D., 102, p.23,337-23343.

Blanken, P.D., T.A. Black, P.C. Yang, **H.H. Neumann**, Z. Nesic, **R. Staebler**, **G. den Hartog**, M.D. Novak and X. Lee 1997: "Energy balance and canopy conductance of a boreal aspen forest: Partitioning overstory and understory components", J. Geophys. Res., 102(D24), p.28,915-28,927.

Bonan, G.B., K.J. Davis, D. Baldocchi, D. Fitzjarrald, and **H.H. Neumann** 1997: "Comparison of the NCAR LSM1 land surface model with BOREAS aspen and jack pine tower fluxes", J. Geophys. Res., 102(D24), p.29,065-29,075.

Bunce, N.J., L. Liu, J. Zhu and **D.A. Lane** 1997: Environ. Sci. Technol. , 31, p.2252.

Cortes, D.R., I. Basu, C. W. Sweet, **K. A. Brice, R. M. Hoff,** and R.A. Hites 1997: "Temporal trends in gas-phase concentrations of chlorinated pesticides measured at the shores of the Great Lakes", Environ. Sci. Technol., 32, p. 1920-1927.

Desjardins, R.L., J.I. MacPherson, L. Mahrt, P. Schuepp, E. Pattey, **H.H. Neumann**, D. Baldocchi, S. Wofsy, D. Fitzjarrald, H. McCaughey, and D.W. Joiner 1997: "Scaling up flux measurements for the boreal forest using aircraft-tower combinations", J. Geophys. Res., 102(D24), p.29,125-129,133.

Donovan, D.P., **H. Fast**, Y. Makino, J.C. Bird, A.I. Carswell, **J. Davies**, T.J. Duck, J.W. Kaminski, **C.T. McElroy**, **R.L.** Mittermeier, S.R. Pal, V. Savastiouk, D. Velkov and J.A. Whiteway 1997: "Ozone, column ClO, and PSC measurements made at the NDSC Eureka observatory (80N, 86W) during the spring of 1997", Geophys. Res.Lett., 24, p.2709-2712.

Fioletov, V.E., J.B. Kerr, D.I. Wardle, J. Davies, E.W. Hare, C.T. McElroy and **D.W. Tarasick** 1997: "Long-term decline of ozone over the Canadian Arctic to early 1997 from ground-based and balloon sonde measurements", Geophys. Res. Lett., 24, p.2705-2708.

Guelle, W. Y., M. Balkanski, M. Schulz, F. Dulac, J. M. Prospero, D. Winker, **R. Hoff** and P. Chazette 1997: "Modeling the vertical and horizontal distribution of the mineral aerosol: comparison with observations", J Aerosol Sci., 28/Suppl.I, S449-S450.

Gultepe, I., G.A. Isaac, C.M. Banic, J.W. Strapp, and **K.B. Strawbridge** 1997: "Use of extinction meter, FSSP, and LANDSAT observations for estimation of microphysical parameters in stratiform clouds during RACE", European Symposium on Aerospace Remote Sensing, London, SPIE Vol. 3220.

Hayden, K. L., K. G. Anlauf, R.M. Hoff, J.W. Strapp, **J.W. Bottenheim, H.A. Wiebe, F. A. Froude, J. B. Martin**, D.G. Steyn, and I.G. McKendry 1997: "The vertical chemical and meteorological structure of the boundary layer in the Lower Fraser Valley during Pacific '93", Atmospheric Environment, 31, p.2089-2105.

Hillery, B. R., I. Basu, **R. M. Hoff**, A. Bandemehr, W. M. J. Strachan, C. H. Chan, C.W. Sweet and R. A. Hites 1997: "Atmospheric deposition of toxic pollutants to the Great Lakes as measured by the Integrated Atmospheric Deposition Network", Environ. Sci. Technol., 32, p. 2216-2221.

Hines, C.O., and **D.W. Tarasick** 1997: "Layer truncation and the Eulerian/Lagrangian duality in the theory of airglow fluctuations induced by gravity waves", J. Atmos. Terr. Phys., 59, p.327-334.

Hoff, R. M. and M.P. McCormick 1997: "Remote sensing of stratospheric aerosols, clouds and gases, in the stratosphere and its role in the climate system", G. Brasseur, ed. NATO Advanced Study Institute Series, 154, p.325-344.

Hoff, R. M., W. M. J. Strachan, C.W. Sweet, C. H. Chan, M. Shackleton, **T.F. Bidleman, K.A. Brice**, D.A. Burniston, S. Cussion, D.F.Gatz, K. Harlin, **W.H. Schroeder** 1997: "Atmospheric deposition of toxic chemicals to the Great Lakes: A Review of Data through 1994", (Erratum), Atmos. Environ., 31, p.1585.

Hoff, R.M., K.A. Brice, and C.J. Halsall 1998: "Non-linearity in the slopes of Clausius-Clapeyron Plots for SVOCs", Environ. Sci. Techol., 32, p.1793-1798.

Hoff, R.M., M. Harwood, A. Sheppard, F. Froude, J.B. Martin, and W. Strapp 1997: "Use of airborne lidar to determine aerosol sources and movement in the Lower Fraser Valley (LFV), BC", Atmospheric Environment, 31, p.2123-2134.

Hogg, E.H., T.A. Black, **G. den Hartog, H.H. Neumann**, R. Zimmermann, P.A. Hurdle, P.D. Blanken, Z. Nesic, P.C. Yang, **R.M. Staebler**, K.C. McDonald and R. Oren 1997: "A comparison of sap flow and eddy fluxes of water vapor from a boreal deciduous forest", J.Geophys. Res., 102(D24), p.28,929-28,937.

Knudsen, B.M., N. Larsen, I.S. Mikkelsen, J.-J. Morcrette, G.O. Braathen, E. Kyro, **H. Fast**, H. Gernandt, H. Kanzawa, H. Nakane, V. Dorokhov, V. Yushkov, G. Hansen, M. Gil and R.J. Shearman 1998: "Ozone depletion in and below the Arctic vortex for 1997", Geophys. Res. Lett., 25, p.627-630.

Lam, D.C.L., **K.J. Puckett**, I. Wong, **M.D. Moran**, G. Fenech, D.S. Jeffries, **M.P. Olson**, D.M. Whelpdale, D. McNicol, Y.K.G. Mariam, and C.K. Minns, 1998: "An integrated acid rain assessment model for Canada: from source emission to ecological impact", Water Qual. Res. J. Canada, 33, p.1-17.

Li, Y. F., 1999: "Global technical hexachlorocyclohexane usage and its contamination consequences in environment: from 1948 to 1997", Sci. Total. Environ., 232, p.123-160.

Li, Y. F., D.J. Cai, and A. Singh 1998: "Hexachlorocyclohexane use trends in China and their impact on the environment", Archives of Environmental Contamination and Toxicology, 35, p.688-697.

Li, Y. F., T.F. Bidleman, L.A. Barrie, and L.L. McConnell 1998a: "Global HCHs use trends and their impact on the Arctic", Geophys. Res. Lett, 25, p.39-41.

Li, Y. F., Y. J. Zhang, G. L. Cao, Jian Hui Liu and **L.A. Barrie** 1998: "Distribution of seasonal SO_2 emissions from fuel combustion and industrial activities in Shanxi, China, with 1/6° X 1/4° longitude/latitude resolution", Atmospheric Environment, 33, p.257-265.

Lu, J.Y. and **W.H. Schroeder** 1999: "Comparison of conventional filtration and denuder-based methods for sampling and analysis of particulate mercury in ambient air" Talanta, 49, p.15-24.

Lu, J.Y. and **W.H. Schroeder** 1999: "Sampling and determination of particulate mercury in ambient air: a review", Water, Air, Soil Pollution, 112, p.279-295.

Lu, J.Y., W.H. Schroeder, T. Berg, J. Munthe, D. Schneeberger and F. Schaedlich 1998: "A device for sampling and determination of total particulate mercury in ambient air", Anal. Chem., 70, p.2403-2408.

McKendry, I. M., D.G. Steyn, J. Lundgren, **R.M. Hoff**, W. Strapp, **K. Anlauf, F. Froude, J.B. Martin**, R.M. Banta and L.D. Olivier 1997: "Elevated ozone layers and vertical down-mixing over the Lower Fraser Valley, B. C.", Atmospheric Environment, 31, p.2135-2146.

Nejedly, Z., J. L. Campbell, W. J. Teesdale, J. F. Dlouhy, T. F. Dann, **R. M Hoff, J. R. Brook**, and **H. A. Wiebe** 1998: "Interlaboratory comparison air particulate monitoring data", J. Air Water Management Association., 48, p.386-397.

Oltmans, S.J., A.S. Lefohn, H.E. Scheel, J.M. Harris, H. Levy II, I.E. Galbally, E.-G. Brunke, C.P. Meyer, J.A. Lathrop, B.J. Johnson , D.S. Shadwick, E. Cuevas, F.J. Schmidlin, **D.W. Tarasick**, H. Claude, **J.B. Kerr**, O. Uchino and V. Mohnen 1998: "Trends of ozone in the troposphere", Geophys. Res. Lett., 25, p.139-142.

Pryor, S. C., R. Simpson, **L. Guise-Bagley, R. Hoff** and S. Sakiyama 1997: "Visibility and aerosol composition in the Fraser Valley during REVEAL. J.", Air Waste Management Assoc. 47, p.147-156.

Pryor, S.C., R.J. Barthelmie, **R.M. Hoff**, S. Sakiyama, R. Simpson and D.G. Steyn 1997: "Characterizing fine aerosols in the Fraser Valley", Atmosphere-Ocean, 35, p.209-227.

Rex, M., N.R.P. Harris, P. Von der Gathen, R. Lehmann, G.O. Braathen, E. Reimer, A. Beck, M.P. Chipperfield, R. Alfier, M. Allaart, F. O'Connor, H. Dier, V. Dorokhov, **H. Fast**, M. Gil, E. Kyro, Z. Litynska, I.S. Mikkelsen, M.G. Molyneux, H. Nakane, J. Notholt, M. Rummukainen, P. Vlatte and J. Wenger 1997: "Prolonged stratospheric ozone loss in the 1995-96 Arctic winter", Nature, 389, p.835-838.

Schroeder W.H., K G. Anlauf, L.A. Barrie, T. Berg, D.R. Schneeberger, **J.Y. Lu** and **A. Steffen** 1998: "Arctic springtime depletion of mercury", Nature, 394, p.331-332.

Schroeder, W.H. and J. Munthe 1998: "Atmospheric mercury — An overview", Atmos. Environ. 32: p.809-822.

Simpson, I.J., G.C. Edwards, G.W. Thurtell, **G. den Hartog, H.H. Neumann** and **R.M. Staebler** 1997: "Micrometeorological measurements of methane and nitrous oxide exchange above a boreal aspen forest", J. Geophys. Res., 102(D24), p.29,331-29,341.

Sirois A. 1997: "Temporal variation of oxides of sulphur and nitrogen in ambient air in Eastern Canada: 1979-1994", Tellus, 49, p.270-291.

Strawbridge, K.B. 1997: "Airborne lidar results during RACE", in Optical Remote Sensing of the Atmosphere, 1997 Technical Digest Series, 5, p.134-136.

Strawbridge, K.B. and **S.-M. Li** 1997: "Optical properties of aerosols obtained from airborne lidar and several in-situ instruments during RACE", in Lidar Atmospheric Monitoring, Proceedings of EOS/SPIE, 3104, p.204-211.

Vermette, S., S. Lindberg, and N. Bloom, 1995: "Field test for a regional deposition network - sampling design and preliminary test results", Atmospheric Environment, 29 (11), p.1247-1251.

Wania, F., D. Mackay, **Y.F. Li**, and **T.F. Bidleman** 1998: "Global chemical fate of α-hexachlorocyclohexane. 1. Evaluation of a global distribution model", Environmental Toxicology and Chemistry, 18, p.1390-1399.

OTHER PUBLICATIONS 1997/98

Barrie, L., R. Macdonald, **T. Bidleman**, M. Diamond, D. Gregor, R. Semkin, W. Strachan, M. Alaee, S. Backus, M.Bewers, Gobeil, C. Halsall, J. Hoff, **A. Li.**, L. Lockhart, D. Mackay, D. Muir, **J. Pudykiewicz**, K. Reimer, J. Smith, G. Stern, **W. Schroeder**, R. Wagemann, F. Wania and M. Yunker 1997: "Sources, occurrence and pathways", Canadian Arctic Contaminants Assessment Report, J. Jensen, K. Adare and R. Shearer (Eds.), Indian and Northern Affairs Canada, Ottawa, Ontario, 2, p.25-182.

Bridgman, H.A., **J.L. Walmsley** and R.S. Schemenauer 1997: "Estimating the spatial distribution of fogwater and acid ion deposition in mountainous terrain", Proceedings, International Workshop on the Monitoring and Prediction of Acid Rain, 29 September - 1 October 1997, Seoul, Korea. S.-U. Park (ed.), Seoul National University, Seoul, p.63-68.

Burrows, W.R., **J.L. Walmsley**, J. Montpetit and M. Faucher 1998: "CART - Neuro-fuzzy statistical data modeling Part 2: Results", 14th Conference on Probability and Statistics in the Atmospheric Sciences, Phoenix, January 1998, American Meteorological Society, Boston, AZ, p.11-16.

Dolan, D.M., K.P. McGunagle, S. Perry and **E. Voldner**, 1993: "Source investigation for Lake Superior", International Joint Commission, Windsor, Ontario, p.56.

Guise-Bagley, L.F. and **R.M. Hoff** 1997: "Ambient vs. dried aerosol light scattering measurements at Egbert, Ontario, Canada, in visual air quality: Aerosols and global radiation balance", Air & Waste Management Association, Pittsburgh, PA, p.1021-1026.

Gultepe,I, G.A. Isaac, **K.B. Strawbridge**, C.M. Banic and W.R. Leaitch 1997: "Comparisons of cloud microphysical and optical parameters obtained from aircraft, satellite, and lidar observations during RACE", Proceedings from the 7th Conference on Climate Variations (77th AMS Annual Meeting, Long Beach, CA, USA,).

Hoff, R., L. Guise-Bagley, M.D. Moran, K. McDonald, Z. Nejedley, I. Campbell, S. Pryor, Y. Golestani, and W. Malm 1997: "Recent visibility measurements in Canada", 90th AWMA Annual Meeting, June 8-13, Toronto, Canada, Air & Waste Management Association, Pittsburgh Paper 97-WA70.05

Hoff, R.M., L. Guise-Bagley, M. Moran, K. McDonald, Z. Nejedly, J.I. Campbell, S. Pryor, S. Golestani and W. Malm: "Recent visibility measurements in Canada, Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada".

IADN Steering Committee 1998: "Technical summary of progress under the Integrated Atmospheric Deposition Program 1990-1996", U.S.E.P.A. and Environment Canada, 4905 Dufferin Street, Toronto, ON M3H 5T4, p.107.

Jensen, J., K. Adare and R. Shearer 1997: "Canadian Arctic Contaminants Assessment Report", Indian and Northern Affairs Canada, Ottawa, Ontario K1A 0H4.

Lane, D.A., N.J. Bunce, L. Liu and J. Zhu 1997: "Products of the reaction of naphthalene with the OH radical in air", American Chemical Society conference, San Francisco, April 13-17, 1997.

Lane, D.A., S. S. Fielder and S. J. Townsend 1997: "An overview of the first stable products and their short-lived intermediate precursors in the OH-naphthalene reactant system in the environment of a smog chamber", International Symposium on Polycyclic Aromatic Compounds, Charlotte, NC, September.

Makino, Y., Y. Tsutsumi, Y. Sawa, **H. Fast**, K. Kondo Miyagawa 1997: "IR-spectroscopic measurements of stratospheric minor constituents over Tsukuba, Japan and Eureka, Canadian Arctic", Proceedings of the Tsukuba International Workshop on Stratospheric Change and its Role in Climate and on the ATMOS-C1 Satellite Mission, Tsukuba, Japan, October 20-22, 1997.

McDonald, K., D. Fox, **R. Hoff** and **L. Guise-Bagley** 1997: "Identification of air corridors impacting the Waterton-Glacier International Park, in Visual Air Quality: Aerosols and Global Radiation Balance", Air & Waste Management Association, Pittsburgh, PA, p.156-165.

McMillan A.C., D. MacIver and **W.B. Sukloff** 1997: "Atmospheric environmental information - An overview with Canadian examples", Environmental Software Systems, Editors R. Denzer, D.A. Swayne and G. Schimak, Chapman & Hall, 1997, 2.

Moran, M.D., 1997: "Evaluation of the impact of North American SO_2 emission control legislation on the attainment of SO_4 critical loads in eastern Canada", 90th AWMA Annual Meeting, June 8-13, Toronto, Canada, Air & Waste Management Association, Pittsburgh. Paper 97-TA28.01

Moran, M.D., M.T. Scholtz, C.F. Slama, A. Dorkalam, A. Taylor, N.S. Ting, D.Davies, **P.A. Makar**, and **S. Venkatesh** 1997: "An overview of CEPS1.0: Version 1.0 of the Canadian Emissions Processing System for regional-scale air quality models", 7th AWMA Emission Inventory Symp., Oct. 28-30, Research Triangle Park, North Carolina, Air & Waste Management Association, Pittsburgh.

Moran, M.D.1998: "Operational evaluation of ADOM seasonal performance with surface data from the Eulerian Model Evaluation Field Study", 10th AMS/AWMA Joint Conf. on Applications of Air Pollution Meteorology, Jan. 11-16, Phoenix, Arizona, American Meteorological Society, Boston, p.404-408.

Nagai, T., M. Hirota, T. Fujimoto, O. Uchino, T. Itabe, K. Mizutani, M. Yasui, T. Shibata, **H. Fast**, A.I. Carswell, B. Liley and W.A. Mathews 1997: "Observations of stratospheric aerosols in the mid and high latitude using a global lidar network", Proceedings of the Tsukuba International Workshop on Stratospheric Change and its Role in Climate and on the ATMOS-C1 Satellite Mission, Tsukuba, Japan, October 20-22, 1997.

Pryor, S.C., **R.M. Hoff**, R.J. Barthelmie, I.G. McKendry 1997: "Vertical and horizontal homogeneity of aerosol loadings: Observations and modelling, in visual air quality: Aerosols and global radiation balance", Air & Waste Management Association, Pittsburgh, PA, p.516-528.

Rasmussen P.E., M.B. McClenaghan, A.L. Sangster, G.C. Edwards and **W.H. Schroeder** 1997: "Emissions of mercury to the atmosphere: Natural sources and pathways", R.B. Wanty, S.P. Marsh and L.P. Gough (Eds.), 4th International Symposium on Environmental Geochemistry; U.S. Geological Survey Open-File Report OF97-496.

Ro, C. U., A. Sirois, and **R.J. Vet** 1997: "Long-term trends in Canadian precipitation and wet deposition data", Proceedings of 3rd International Joint Seminar on the Regional Deposition Processes in the Atmosphere, Nara, Japan, November 5-7, 1997, p.141-148.

Ro, C. U., R.J. Vet, D. Ord, M. Peters and A. Holloway1998: "National Atmospheric Chemistry Data Base (NAtChem) 1995 Annual Report-NAtChem web site: Acid precipitation in North America", Atmospheric Environment Service, Environment Canada, Downsview, Ontario, Canada.

Ro, C.U. and R.J. Vet 1997: "Temporal variations in wet deposition of SO_4= , NO_3-, H+ and cations in Eastern North America", International Workshop on Monitoring and Prediction of Acid Rain, Seoul, Korea, Sept. 29 - Oct. 1, 1997, p.51-61.

Ro, C.U., A. Sirois and R.J. Vet 1997: "Time trends in Canadian air and precipitation chemistry data", Air & Waste Management Association's 90th Annual Meeting & Exhibition, Toronto, Ontario, Canada, June 8-13, 1997.

Ro, C.U., R.J. Vet and D. Ord 1997: "QA/QC methods applied to Canadian precipitation chemistry data", EMEP-WMO Workshop on Data Analysis, Validation and Reporting, Usti nad Labem, Czech Republic, April 27-30, 1997, p.139-158.

Ro, C.U., R.J. Vet, D. Ord and A. Holloway1998: "Canadian Air and Precipitation Monitoring Network (CAPMoN) annual summary reports (1983-1996)", Air Quality Research Branch, Atmospheric Environment Service, Environment Canada, Downsview, Ontario, Canada.

Ro, C.U., R.J. Vet, D. Ord and K.A. Parkhill 1998: " National Atmospheric Chemistry Data Base (NAtChem) analysis report (1980-1994)", Air Quality Research Branch, Atmospheric Environment Service, Environment Canada, Downsview, Ontario, Canada.

Rowlands, N., G. Buttner, A. Raab, G. Shepherd, W. Gault, M. Cann, S. Dobbie, S. Sargoytchev, Y. Rochon, W. Ward, R. Mani and **D. Tarasick** 1998: "SWIFT: Stratospheric wind interferometer for transport studies", NSERC/CSA Industrial Cooperative Research.

Salmon, J.R. and **J.L. Walmsley** 1997: "Testing a correlation model for wind speed and direction estimates", Second European and African Conference on Wind Engineering, Genova, Italy, 22-26 June 1997, 1. G. Solari (ed.), University of Genova, Genova, p.189-196.

Schroeder W.H., K. Anlauf , L.A. Barrie, T. Berg and D.R. Schneeberger D.R. 1997: "Atmospheric mercury and Polar Sunrise tropospheric depletion at Alert in the Canadian High Arctic", AMAP International Symposium on Environmental Pollution in the Arctic, Arctic Monitoring and Assessment Program, Oslo, Norway., p.354-356.

Schroeder W.H., K.G. Anlauf., L.A. Barrie, A. Steffen and **J.Y. Lu** 1998: "Depletion of mercury vapour in the arctic troposphere after Polar Sunrise", EUROTRAC-2 Symposium on Transport and Chemical Transformation in the Troposphere, P.M. Borrell and P. Borrell (Eds.), Witpress, Southampton, p. 358-362.

Schroeder, W. H., G. Keeler, H. Kock, P. Roussel, D. Schneeberger, and F. Schaedlich, 1995: " International field intercomparison of atmospheric mercury measurement methods", Water, Air, Soil Pollut., 80, p.611-620.

Schroeder, W.H., 1996: "Estimation of atmospheric input and evasion fluxes of mercury to and from the Great Lakes", Global and Regional Mercury Cycles: Sources , Fluxes and Mass Balances, W. Baeyens et al. (eds), Kluwer Academic Publishers, Netherlands, p.109-121.

Smit, H.G.J., W. Strater, M. Helten, D. Kley, A. Ciupa, H.J. Claude, U. Kohler, B. Hoegger, G. Levrat, B. Johnson, S.J. Oltmans, **J.B. Kerr, D.W.Tarasick, J. Davies,** M. Shitamichi, S.K. Srivastav and C. Vialle 1996: "JOSIE: The 1996 WMO international intercomparison of ozonesondes under quasi-flight conditions in the environmental chamber at Julich", "Atmospheric Ozone", Proc. XVIII Quad. O3 Symp., (l'Aquila, Italy, 1996), ed. R.D. Bojkov and G.V. Visconti, Edigrafital, Italy, 1998.

Steyn, D.G., H.-P. Schmid, **J.L. Walmsley** and J.D. Wilson 1997: "Spatial variability in surface climates", The Surface Climates of Canada. W.G. Bailey, T.R. Oke and W.R. Rouse (eds.), McGill-Queens Press, Montreal, p.44-67.

Tarasick, D.W., G. Brunet, R. Daley, P. Gauthier and W.E. Ward 1996: "A Canadian middle atmosphere initiative, in "Atmospheric Ozone", Proc. XVIII Quad. O3 Symp., (l'Aquila, Italy, 1996), ed. R.D. Bojkov and G.V. Visconti, Edigrafital, Italy, 1998.

Tarasick, D.W., J. Davies, K. Anlauf and **M. Watt** 1996: "Response of ECC and Brewer-Mast sondes to tropospheric ozone, "Atmospheric Ozone", Proc. XVIII Quad. O3 Symp., (l'Aquila, Italy, 1996), ed. R.D. Bojkov and G.V. Visconti, Edigrafital, Italy, 1998.

Tarasick, D.W., J.B. Kerr, D.I. Wardle, J.J. Bellefleur, S. Bunka and **J. Davies** 1996: "Tropospheric ozone trends at Canadian stations: 1980--1995, "Atmospheric Ozone", Proc. XVIII Quad. O3 Symp., (l'Aquila, Italy, 1996), ed. R.D. Bojkov and G.V. Visconti, Edigrafital, Italy, 1998.

Tarasick, D.W., V.E. Fioletov, T.G. Shepherd, J.C. McConnell, W.F.J. Evans, R. Gallagher, M. Morrison, K. Percy, H. Vaughan, J. Cullen and R. Alward 1997: "Ozone science: A Canadian perspective on the changing ozone layer", Edited by D.I. Wardle, J.B. Kerr, C.T. McElroy and D.R. Francis, Environment Canada, University of Toronto Press, Toronto.

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DATE: 1997/1998

OTM ANNUAL REPORT