the air around us

Air Quality Research Branch **annual report** **2003 : 2004**

Environment Canada
Meteorological Service of Canada

Environnement Canada
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Canada

Table of Contents

Director's Message

This annual report highlights the activities of the Air Quality Research Branch (AQRB) and reports on the progress made in the 2003/2004 fiscal year.

The management of air quality is of great concern to Canadians. In light of the increasing awareness of the impacts of air quality on human and ecosystem health, regulators are relying heavily on science to help define policies that reduce air pollution and protect Canadians.

In the last fiscal year, the AQRB has made several major achievements in the areas of research on smog, acidic deposition, hazardous air pollutants, greenhouse gases and aerosols, stratospheric ozone, and air quality predictions. For instance, the Branch took significant steps in strengthening its collaboration with the Canadian Meteorological Centre (CMC) and in transferring air quality modelling technologies to the Centre to produce reliable real-time air quality forecasts for Canadians. Last summer, the MAESTRO (Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation), a leading-edge technological instrument developed by AQRB scientists, was launched into space aboard the Canadian Space Agency (CSA) SCISAT-1 satellite to measure ozone in the stratosphere. Another milestone was the initiation of smog-related research activities with several Environment Canada regional offices as part of the Canada-U.S. Border Air Quality Strategy.

The AQRB's research and development (R&D) activities include:

- measurement and monitoring of air quality trends to help set targets to improve the quality of the nation's air and to prevent deterioration in areas where the air is relatively free of contamination;
- development of air quality models to ascertain and evaluate air quality, and predict the behaviour of atmospheric substances; and
- experiments and extensive field studies to achieve a better understanding of chemicals and their behaviour in the atmosphere.

Effective partnerships with organizations such as universities, research institutions, international agencies, Environment Canada services and regions, and other government departments play a key role in strengthening the AQRB's research capacity.

The Branch's R&D work is a key component of air quality services. This scientific work supports policies to reduce air pollution and protect human and ecosystem health. The Branch's R&D work also feeds into air quality forecasts, UVB indices and health impact studies to provide Canadians with up-to-date information on air quality allowing them to take action to protect themselves from air pollution and harmful exposure to the sun. Through research collaborations, peer-reviewed journal publications, field tours and presentations, the Branch also shares research results with the research community to advance the state of knowledge of air quality.

The Branch continues to provide credible and relevant science for the development of sound public policy and services to Canadians in efforts to help them improve their quality of life.

Dr. Keith J. Puckett

Air Quality Research Branch

- The Air Quality Research Branch (AQRB), formed in 1971, is one of the branches of the Atmospheric and Climate Science Directorate (ACSD), Meteorological Service of Canada (MSC), Environment Canada. Staff in the Branch study the chemistry and physics of the atmosphere, how it is changing over time, and a variety of atmospheric pollution problems. The staff are the largest group of atmospheric chemistry specialists in Canada.
- The Branch is composed of four divisions as well as a finance and administration office, a centre for atmospheric research experiments (CARE) and an air quality models application group (Figure 1), which is closely allied with the Canadian Meteorological Centre (CMC). The Branch operates the Canadian Atmospheric Research Laboratory (also know as the Thomson Lab) to perform its chemical analyses.
- The AQRB conducts business under six major programs: smog, acidic deposition, hazardous air pollutants, greenhouse gases and aerosols, stratospheric ozone, and air quality predictions and model applications and carries out air quality research to:
  - better understand how atmospheric pollutants affect the chemical and physical behaviour of the atmosphere;
  - determine the composition and concentration of atmospheric pollutants to support health impacts research;
  - provide the scientific basis for policy development;
  - provide Canadians with air quality information through air quality predictions; and
  - share expertise on air quality science with research communities to enhance the scientific knowledge base.

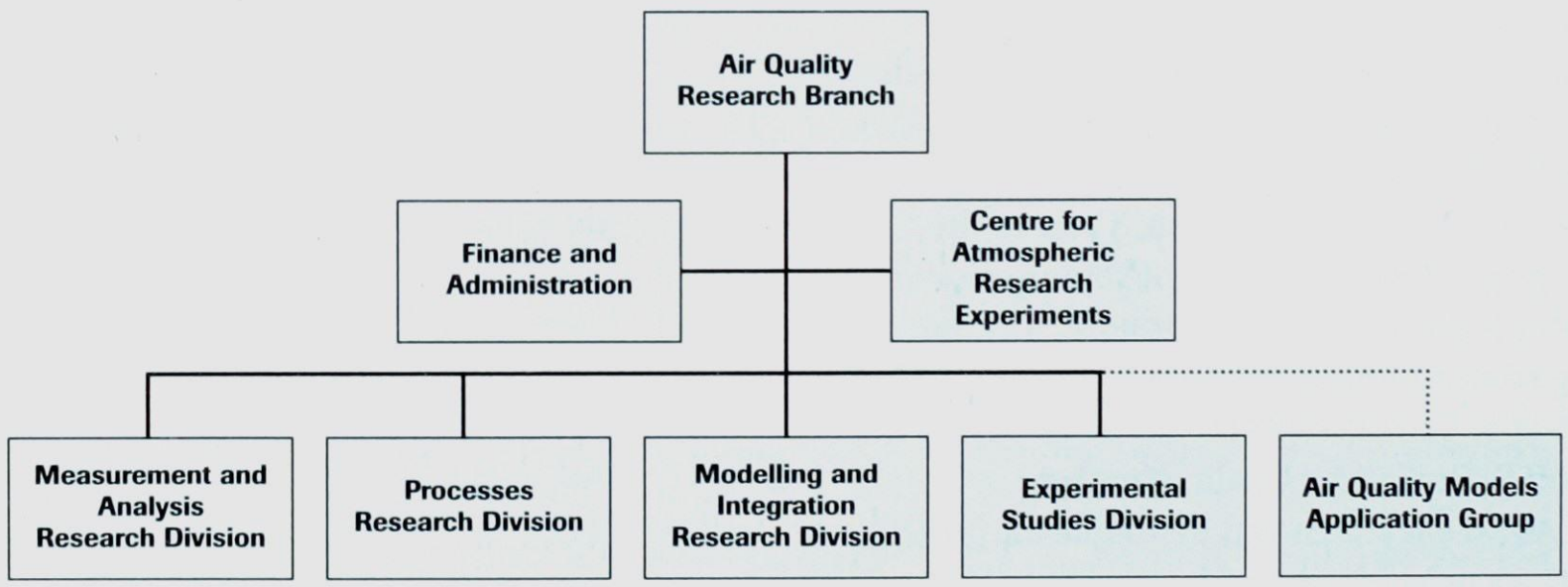


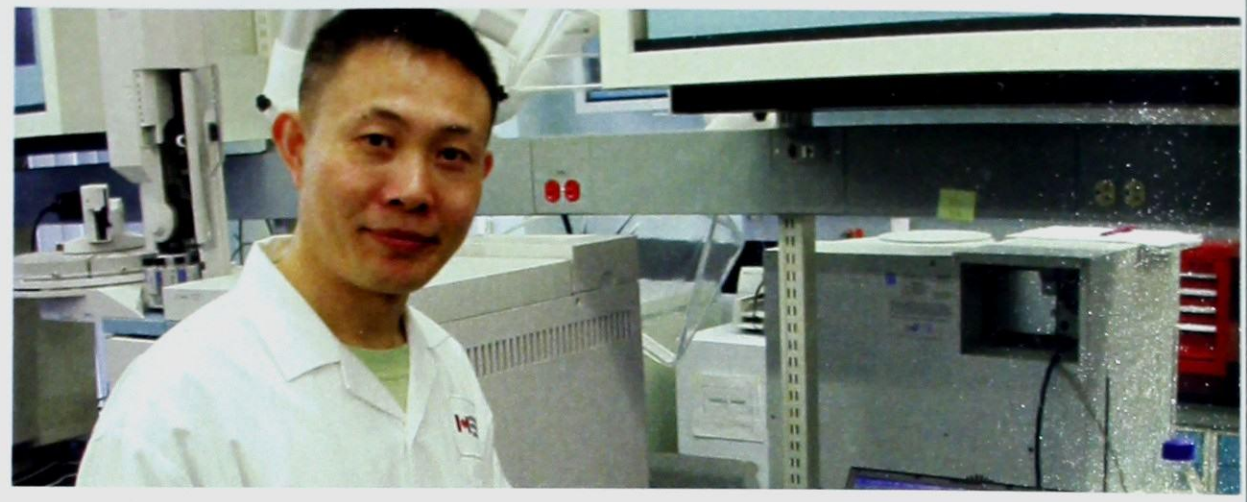
Figure 1 – Air Quality Research Branch organizational chart

Smog

The Smog Research Program is in direct support of the Federal Government's Clean Air Agenda, with key priorities being the development of Canada-Wide Standards (CWS) for Particulate Matter (PM) and Ozone, the provision of advice and information to support the development and implementation of the Canada-U.S. Air Quality Agreement and services to the Canadian public such as air quality forecasting.

The Program's overall objective is:

To determine the quantitative relationships between primary particulate matter and precursor gas emission sources, and ambient $PM_{2.5}$, PM_{10} and ozone levels for all regions of Canada.



Smog-related activities in the last fiscal year include identification of smog sources through systematic measurements and data analysis of ozone and PM, smog modelling and various smog studies.

Systematic Measurements of Ozone & PM

- The Canadian Air and Precipitation Monitoring Network (CAPMoN) has been in operation for over 20 years. Its initial focus was on acid rain, but now the network also supports the smog and air quality prediction programs. CAPMoN sites are chosen to ensure that measurements represent the regional composition of the atmosphere (Figure 2). Data from CAPMoN have been used for the assessment of transboundary transport between Canada and the U.S. to determine the effectiveness of acid gas emission control programs, to evaluate the accuracy of air quality models, and as input to effects assessment programs.

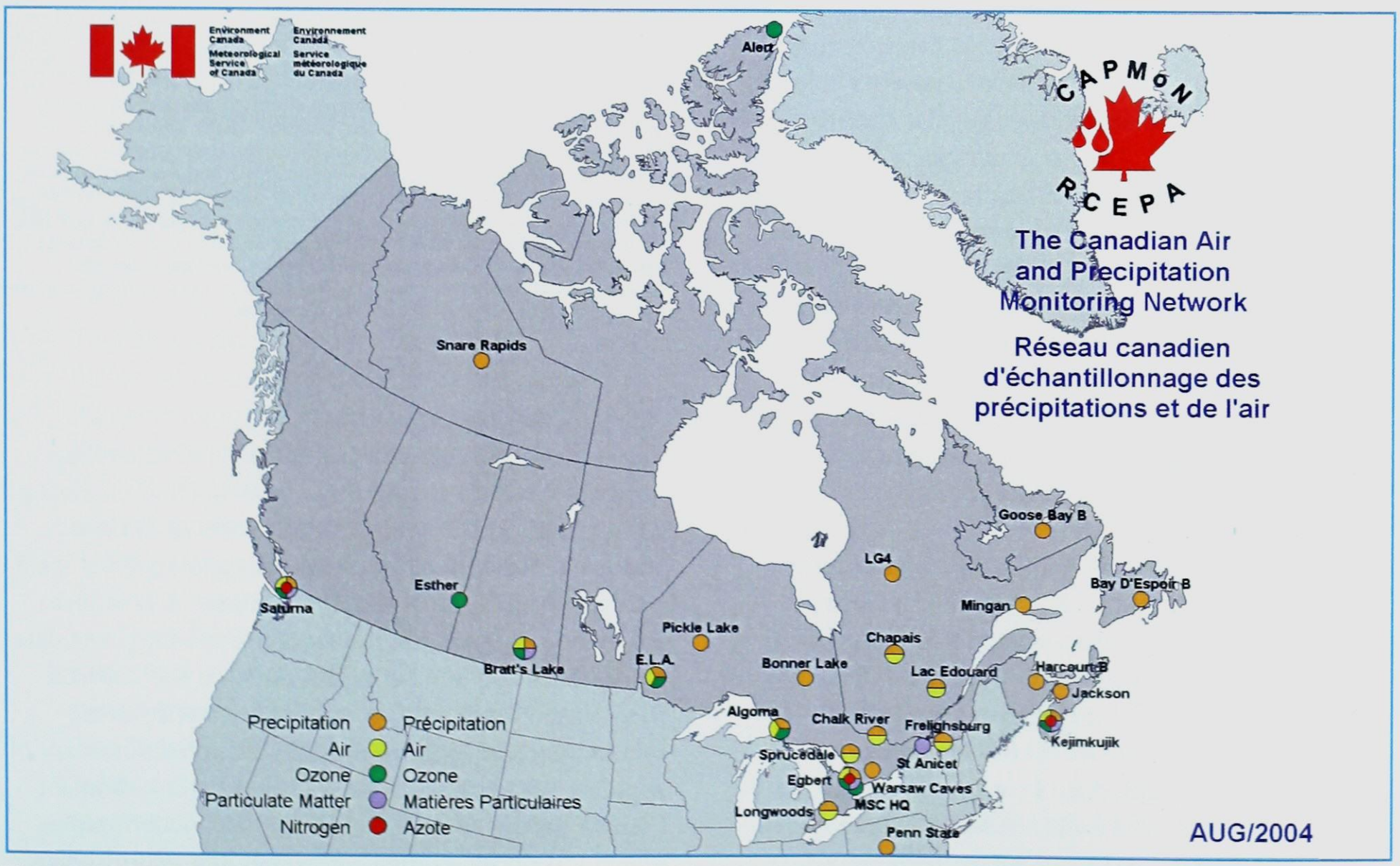


Figure 2 – CAPMoN measurement sites

- CAPMoN's aging ozone analyzers have been replaced at six sites and continuous ozone measurements have been added at Alert, Nunavut and at MSC headquarters in Toronto. High quality real-time ozone data are now being acquired and disseminated for use in both Canada and the U.S. in support of air quality forecasting and episode identification. Instrument acquisition and planning is well underway in support of extending non-urban ozone measurements to an additional eight sites in the 2004/05 fiscal year.
- Work continues on measuring particulate matter with year round 1-in-3 day $PM_{2.5}$ and PM_{10} mass measurements as well as $PM_{2.5}$ speciation measurements continuing at six Branch CORE sites: Saturna, Bratt's Lake, Egbert (CARE), St. Anicet, Kejimkujik and Alert.

  CORE network sites provide long-term, high quality observations of atmospheric composition and radiation at locations representative of major atmospheric regimes (and geopolitical regions) across Canada. The CORE network also supports the research programs described later on in this report.

Sources of Smog ($PM_{2.5}$)

- One of the key components of smog is fine particles ($PM_{2.5}$). Recent data indicate that some parts of Canada, for instance Southern Ontario, will potentially exceed the Canada-Wide Standards for PM in 2010. The Air Quality Research Branch (AQRB) led a multi-year study on the day-to-day changes in the chemical make-up of $PM_{2.5}$ in downtown Toronto, Ontario and Burnaby, British Columbia. A receptor model referred to as Positive Matrix Factorization (PMF), has recently been applied to the first year of data and is a useful method for identifying potential sources of $PM_{2.5}$. This information will help develop or refine strategies for reducing $PM_{2.5}$, which can in turn improve public health.
- The PMF research led by AQRB is noteworthy when compared to similar research conducted at most locations in eastern North America (ENA) and elsewhere due to the availability of a larger list of $PM_{2.5}$ chemical constituents. For instance, the inclusion of concentration measurements of low molecular weight organic acids allowed the PMF model to obtain a more realistic estimate of the contribution of coal combustion and secondary organic aerosols to the formation of $PM_{2.5}$. The results of receptor modelling work (Figure 3) and other trajectory-based analyses (Figure 4) have supported efforts to explore the possibility of a PM Annex to the Canada-US Air Quality Agreement.

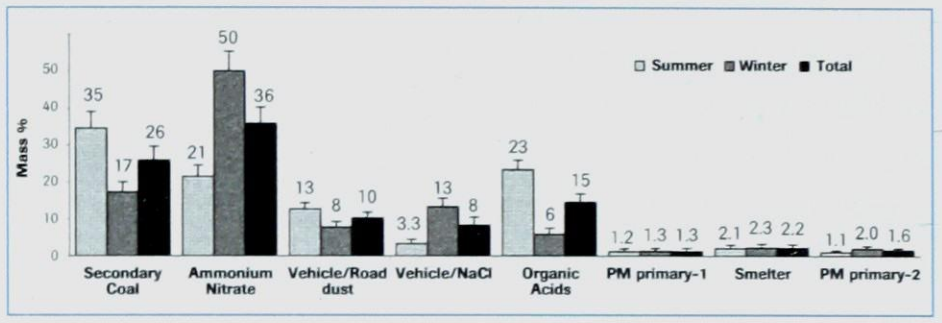


Figure 3 – Percent contribution, by source, to the [$PM_{2.5}$] observed in Toronto, as determined using PMF (summer corresponds to May-October and winter is November-April).

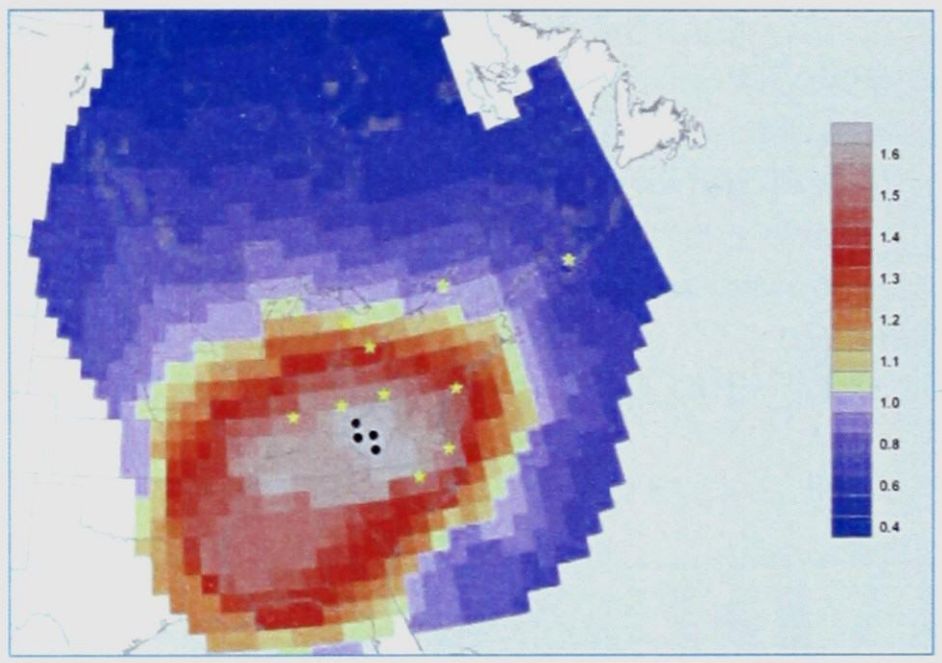


Figure 4 - Trajectory-based analysis showing geographic areas most often contributing to above average $PM_{2.5}$ across multiple locations (yellow stars) in eastern North America. Colour shading indicates percent of average concentrations. Values greater than 1.0 indicate that the area contributes to regionally elevated $PM_{2.5}$. The grey areas are consistent with locations of large SO_2 and NO_x emissions. The black dots highlight grid squares (i.e. locations) with the largest QTBA (Quantitative Transport Bias Analysis) values, which imply the greatest likelihood of contributing to above average regional $PM_{2.5}$ in the warm season.

Analysis of $PM_{2.5}$ and Ozone Data

The National Atmospheric Chemistry (NAtChem) database continued collecting, archiving and analyzing data from air quality monitoring networks in Canada and the U.S. Many requests for data and analyses were addressed using the NAtChem database. A new web-based data access system was developed for particulate matter data and will be implemented in the 2004/05 fiscal year. Figure 5, is an example of a NAtChem product used as input to the 2002 National Summary of Ambient PM2.5 and Ozone prepared by Environment Canada for the Federal-Provincial Joint Action Implementation Coordinating Committee. The figure shows

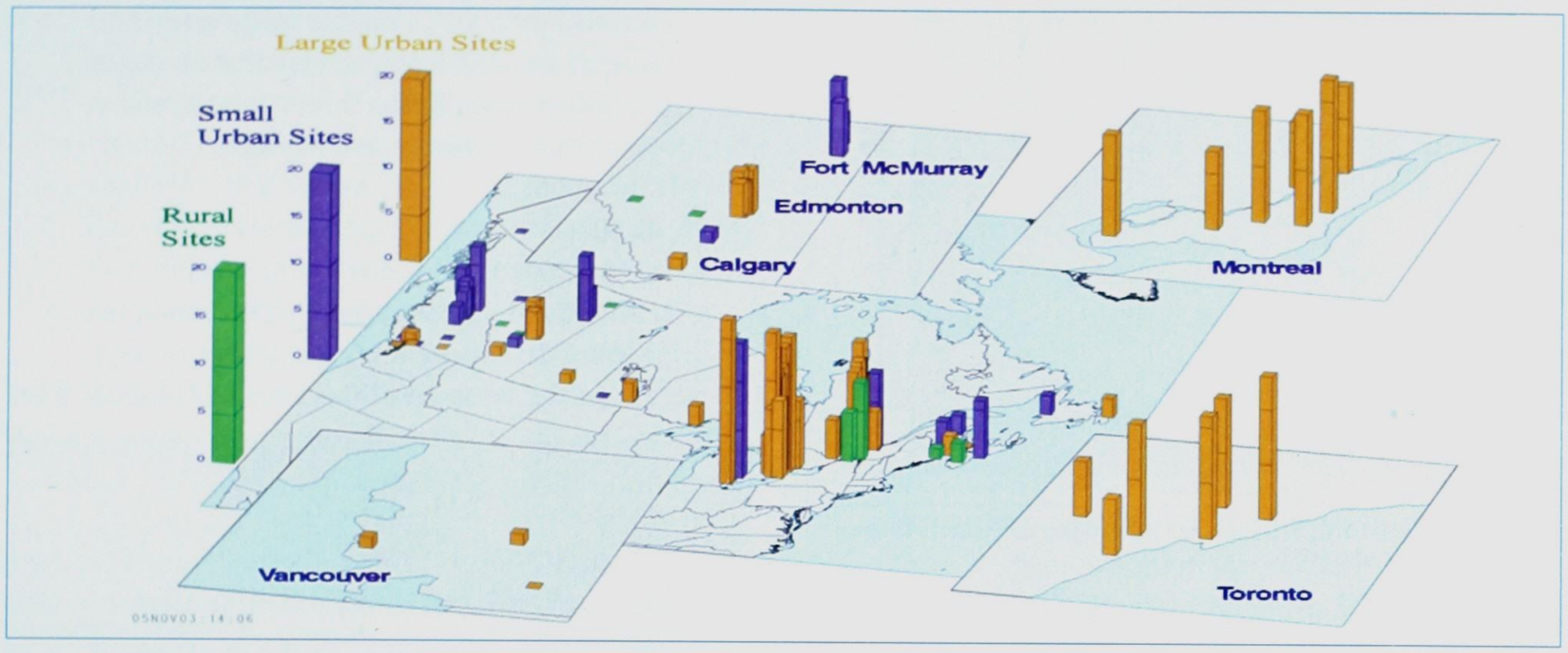


Figure 5 – The number of daily ambient $PM_{2.5}$ concentrations that exceeded 30 µg•m^{-3} at urban and rural monitoring sites in 2002.

the geographical distribution of the number of days in 2002 during which ambient daily PM2.5 concentrations exceeded 30 µg.m-3. Urban and rural monitoring sites in the Windsor (ON) to Quebec corridor exhibited the highest number of exceedances in the country. This information is helpful in monitoring trends and compliance with CWS, and in determining if early actions are needed should trends indicate that the Standards may be exceeded in future years.

Smog Modelling Developments

- **A Unified Regional Air-quality Modelling System**
  Significant progress was made to the MSC regional PM air quality model, known as AURAMS (A Unified Regional Air-quality Modelling System). A new version of AURAMS, version v0.30, was delivered by AQRB to CMC in January 2004. This new version includes the addition of a new meteorological driver (GEM-DM) and a first implementation of scalar and vectorized heterogeneous chemistry parameterizations (ISORROPIA and HETV respectively) and size- and composition-resolved primary PM emissions.

  Preliminary performance evaluations of AURAMS have been carried out for three periods over eastern North America (Aug. 1988, July 1995, Feb. 1998) and for the Pacific 2001 field campaign period (Aug. 2001) over western North America. The Pacific 2001 simulations were compared to a suite of measurements from the intensive observing period carried out in the Lower Fraser Valley of British Columbia. The latter have been instrumental in suggesting a number of science improvements to the model code.

  Five AURAMS future-year emission-control scenarios were also run for both a summer and a winter period for inclusion in the 2004 Environment Canada/U.S. Environmental Protection Agency (EPA) PM Transboundary Transport working group report, which was prepared under the Canada-U.S. Air Quality Agreement. This effort represents the first policy application of AURAMS. Two significant findings are that changes in atmospheric PM in eastern North America in response to changes in PM gaseous precursors are expected to vary strongly by season and in some areas to vary non-proportionally and even non-directionally (that is, a decrease in emissions of PM gaseous precursors will result in an increase rather than a decrease in PM concentrations).
- **Canadian Hemispheric and Regional Ozone and NO_x System**
  CHRONOS (Canadian Hemispheric and Regional Ozone and NO_x System) is a comprehensive air quality model containing a full description of atmospheric chemistry and meteorological processes. In the 2003/04 fiscal year, the development of air quality forecasting tools progressed along three main paths including changes in the computing environment, development of data assimilation and testing updated numerical techniques. In the area of computing the CHRONOS code was converted to be executed on the IBM super computer. With this

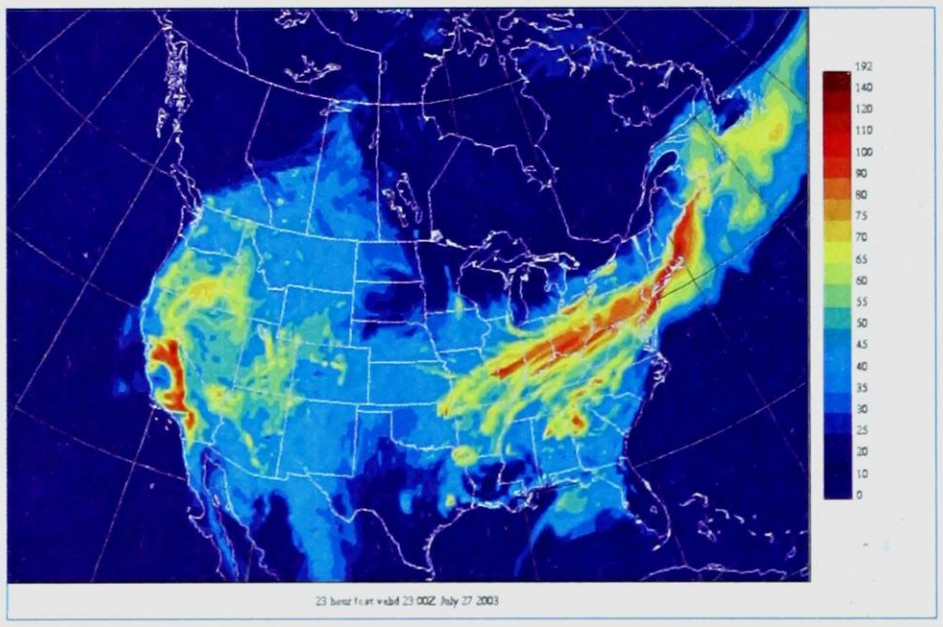


Figure 6. Typical CHRONOS output illustrating the effects of long-range transport of ozone

conversion, CHRONOS continues to be run within operational constraints of two hours of CPU time per 48 hour forecast.

An assimilation scheme, based on the theory of optimal interpolation, combining CHRONOS model outputs with the US-EPA AIRNow database (which also includes data from Canadian stations) has been built during the past fiscal year. This scheme permits off-line or on-line assimilation of surface ozone. Off-line mode is mainly used for the production of a real-time Objective Analysis (OA) map which is available to users through Environment Canada web pages (http://www.msc-smc.ec.gc.ca/aq_smog/analysis_e.html). The on-line mode is used for research and development, real-time air quality forecasting (assimilation from 0 to 12Z) and reanalysis (continuous assimilation).

Smog Studies

- **Pacific 2001 Field Study**

  One of the high priorities for the smog research program during the reporting year was the continuous work-up of the data and samples from the Pacific 2001 Field Study, which took place in the Vancouver area in the summer of 2001. The success of the study is witnessed in part by the 15 papers accepted for publication and expected to appear in a special issue of *Atmospheric Environment* in summer 2004. This issue of *Atmospheric Environment* will be devoted to the Field Study. A second issue of *Atmospheric Environment* will feature additional papers on the Pacific 2001 Air Quality Study. Several papers have been submitted and several more are being prepared for the second issue. The Pacific 2001 Field Study has been a success and has generated some relevant research papers to advance the state of knowledge and understanding on the behaviour of the atmospheric chemicals involved in smog.

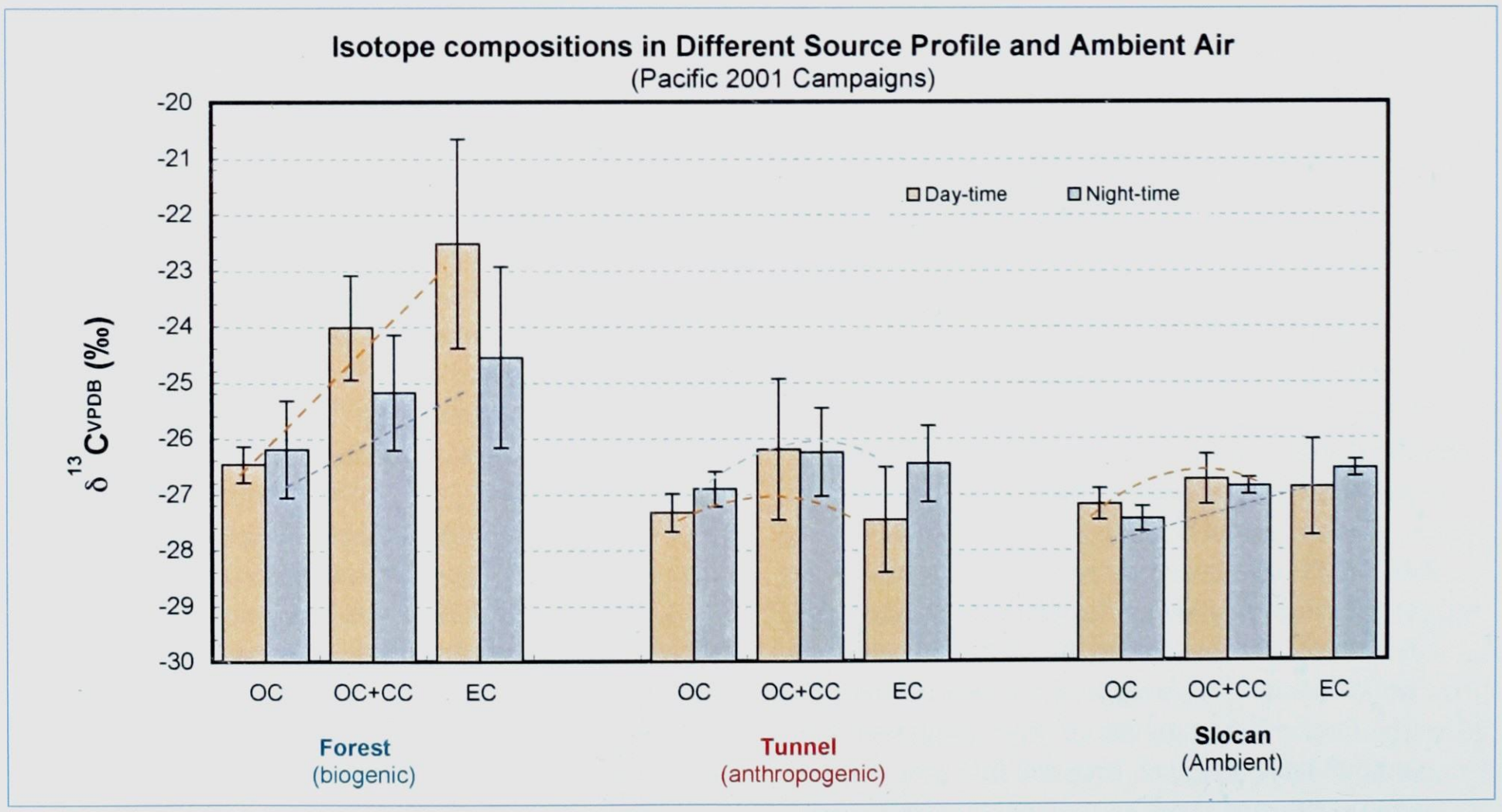


Figure 7 – Carbon isotope measurements of different carbon species i.e. OC/EC (organic carbon and elemental carbon) in PM for source identification & apportionment (i.e. anthropogenic vs. biogenic) in ambient aerosols.

A major goal of the Pacific 2001 Study was to improve the ability to distinguish between anthropogenic and biogenic sources of PM. Figure 7, highlights one method – carbon isotopes analysis – that shows that PM at the forest site has very different carbon isotope ratios signature than the two urban sites.

- **Air Chemistry at a High-Elevation Pacific Site**
  In 2003, sampling at a high elevation site (2182 m altitude) on Canada's west coast continued for the second year of the initial three-year study. The site is located in Whistler, BC (50N, 123W), approximately 115 km from Vancouver in the Coast Mountains. Air measurements taken at the site include ozone, carbon monoxide (CO), inorganic particle chemistry, particle size distributions, seasonally-averaged persistent organic pollutants (POPs) and meteorological parameters. Over the two-year period, ozone and CO exhibited typical annual cycles with springtime maxima, but monthly-averaged concentrations of both species during summer 2003 were approximately twenty percent higher than during the previous year. These increased concentrations along with the influence of biomass burning and trans-Pacific transport are being investigated.

Figure 8 – Whistler Peak measurement site with the sampling hut circled.

These high-elevation background measurements are important in providing information on the climatology of particle and gas-phase species in the lower free troposphere. This information will be used to document the frequency and duration of incidences of trans-Pacific pollution transport to the west coast of Canada.

- **Smog and the Health Linkages**
  The Air Quality Research Branch has had an important role in assisting Health Canada in many of their past air quality health effects studies. The latest nationwide analysis of the association between smog (all criteria air pollutants) and mortality was undertaken with Health Canada and is now being used to update statistics on the overall impact on the Canadian population and to develop and revise the Canadian air quality index.

  The Branch has also had a central role in the development and application of a controlled human exposure facility for fine particles and gases at the Gage Occupational and Environmental Health Unit at the University of Toronto. The AQRB and the University of Toronto, in collaboration with the University of Michigan, have been studying the effect of fine particles and gases on the human cardiovascular system at two-hour exposures to 150 mg/m^3 of $PM_{2.5}$ and 120 ppb of ozone. In the 2002/03 fiscal year, the exposure facility research led to a new discovery showing that immediately after the controlled exposure to smog, the volunteers' arteries were observed to have constricted by an average of 0.09 mm. This work was expanded in 2003/04 with a new publication linking the size of the vascular responses among the volunteers to the chemical composition of the particles. The strongest relationship between the size of the brachial artery constriction and chemical constituent concentration was found for organic carbon (Figure 9). This finding potentially provides some insight into the emission sources of

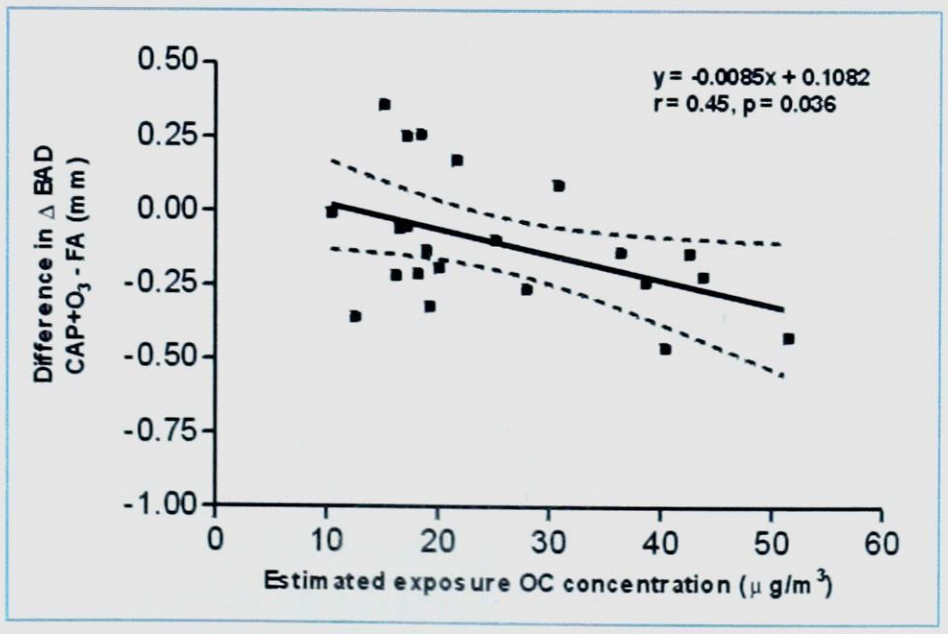


Figure 9 – Relationship between the estimated controlled exposure concentration of total particle-bound organic carbon (OC) and brachial artery constriction (expressed relative to the control exposure to filtered air – FA).

atmospheric fine particles that have a greater impact upon cardiovascular health. In Toronto and other cities, fossil fuel combustion, most notably from motor vehicles, is a large source of the carbon fraction of the particles.

- **Contribution of Natural Aerosols to Canadian PM**

  An initial assessment of the contributions of natural aerosols to the background PM levels in Canada has been completed using the Northern Aerosol Regional Climatological Model (NARCM). Four types of natural PM mass concentrations and their relative contributions were obtained for soil dust, sea-salt, organic carbon (OC) and elemental carbon (EC). Results from the NARCM model indicate that natural sources contribute significantly to the overall PM in Canada (with dust being the major contributor). The model also revealed that natural aerosol components show strong seasonal variations and inter-annual variability. Simulations indicate that dust aerosols mainly contribute to the total PM in the spring-time while biomass burning contributes to the total PM predominantly in the summer.

- **Border Air Quality Strategy (BAQS)**

  In 2003, the BAQS was initiated to build on the Canada-U.S. Air Quality Agreement in efforts to reduce cross-border air pollution between Canada and the U.S. The following major projects will be undertaken as part of the Strategy: a pilot project using an airshed management framework approach to deal with air pollution from domestic and transboundary sources in the Great Lakes region; a project building on the Georgia Basin-Puget Sound transboundary airshed strategy and an emissions trading feasibility study building on the Ozone Annex commitment under the Canada-U.S. Air Quality Agreement.

  Environment Canada and Health Canada are collaboratively leading the initiative. Under this new strategy, the AQRB is focussing on:

  - Linkages between emissions, and fine particle ($PM_{2.5}$) and ozone (O_3) concentrations in the atmosphere and subsequent human exposure levels.
  - Determination of the emission sources, in both Canada and the U.S. that contribute most to population exposure and environmental impacts.

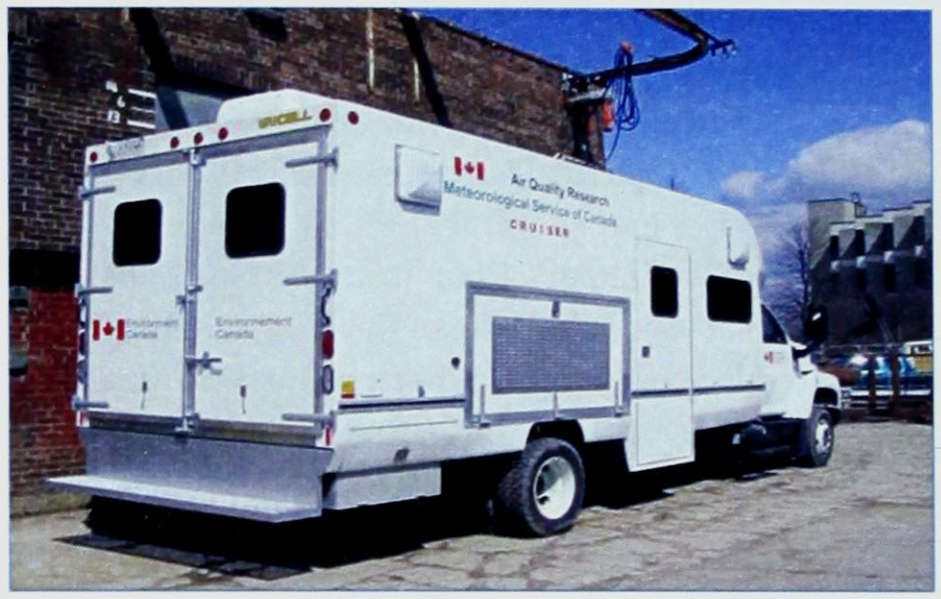


Figure 10 – New AQRB mobile lab known as the Canadian Regional and Urban Investigation System for Environmental Research (CRUISER).

  - Quantification of transboundary and regional transport and deposition of $PM_{2.5}$, O_3 and their precursors as well as of $PM_{2.5}$ constituents.
  - Air quality modelling for investigation of source-receptor relationships, environmental prediction and evaluation of the risks and benefits of air quality management strategies.

  The main tool to be used in the pilot airsheds of south western Ontario and southern BC is a new state-of-the-art mobile laboratory (Figure 10), referred to as CRUISER (Canadian Regional and Urban Investigation System for Environmental Research). Two of the main measurement instruments for CRUISER, an Aerodyne Aerosol Mass Spectrometer for real-time measurement of $PM_{2.5}$ size and composition, and a Proton-Transfer Reaction Mass Spectrometer for real time measurement of VOCs, were acquired and brought into operation in 2003/04. Measurements from these instruments and others on board CRUISER are expected to lead to significant advances in the determination of the primary $PM_{2.5}$ sources in Canada. CRUISER was designed and constructed in 2003/04. Measurement campaigns are expected to begin in the summer of 2004 and a wide variety of other air quality and health studies, primarily being led by Ontario and Pacific & Yukon Regions, and Health Canada, are being planned for 2004-07. The AQRB and its CRUISER mobile lab will contribute to many of these planned activities in the coming years.

Acidic Deposition

The Acidifying Deposition Research Program provides the scientific information needed to meet the following objective:

To reduce acid gas emissions (in terms of magnitude, type, emissions sector, and location) to protect human health and terrestrial and aquatic ecosystems

For the fiscal year 2003/04, the focus was on measurements of acidifying species in air and precipitation, and the associated database, data analysis and interpretation activities, namely:

- CAPMoN measurements and NAtChem data analyses;
- analysis of spatial and temporal trends of wet and dry deposition;
- exploration of new data analysis techniques; and
- development of emission control scenarios

Furthermore, a considerable amount of effort was devoted to the preparation of two chapters for the *2004 Canadian Acid Deposition Science Assessment* – Chapter 3: "Atmospheric Response to Past Emission Control Programs" and Chapter 4: "Current and Proposed Emission Control Programs: How Will Acid Deposition be Affected?".

Systematic Measurements of Acidic Deposition

- The CAPMoN continues to focus on acid deposition measurements along with other air quality measurements. Data from CAPMoN have been used to determine the effectiveness of acid gas emission control programs and to determine if critical loads for acid deposition are still being exceeded in eastern Canada.
- Enhancement of CAPMoN's measurement program has been completed. This augmentation includes two new precipitation measurement sites in Ontario (Pickle Lake and Sprucedale) and two more in Quebec (Lac Eduoard and LG4). In addition, air concentration measurements were added to Sprucedale.

The Nitrogen Scoping Study

Four field campaigns were carried out to measure ambient concentrations of various atmospheric nitrogen compounds at three different CAPMoN sites. The campaigns lasted approximately one month each and took place in different seasons of the year. The final measurement data will be used to assess the relative contributions of NO_3^-, HNO_3, NO_2, and PAN to the total dry deposition flux of nitrogen at the CAPMoN sites. The four studies carried out in the 2003/04 fiscal year, in addition to the seven completed in earlier years; take the total to 11 studies carried out to date. Data from the first three studies carried out in 2001 and 2002 were analyzed to determine the relative contribution of NO_3^-, HNO_3 and NO_2 to nitrogen dry deposition during the measurement periods. Results demonstrate that in addition to HNO_3, NO_2 is a very important contributor to the dry deposition flux of total nitrogen at each site.

Analysis of Acid Deposition Data

- The AQRB continued to collect and archive precipitation chemistry data from U.S. monitoring networks in Canada and the U.S. for the NAtChem database. The merged data were mapped and analyzed to serve as input to the *2004 Canadian Acid Deposition Science Assessment*. NAtChem staff received and filled many formal requests for data, maps and statistical analyses and implemented a new web-based data access system which allows precipitation chemistry data to be downloaded directly over the Web (http://www.msc.ec.gc.ca/natchem/index_e.html). One of the key data analyses provided to the *2004 Canadian Acid Deposition Science Assessment* is shown in Figure 11. It illustrates that eastern Canadian SO_2 emission sources accounted for only 9% of the total sulphur emissions in eastern North America although the same area of eastern Canada received approximately 35% of the wet $SO_4^=$ deposition (expressed as sulphur) that fell in eastern North America. The disproportionately high fraction of wet deposition received in eastern Canada is due to the transboundary transport of American SO_2 emissions into Canada.

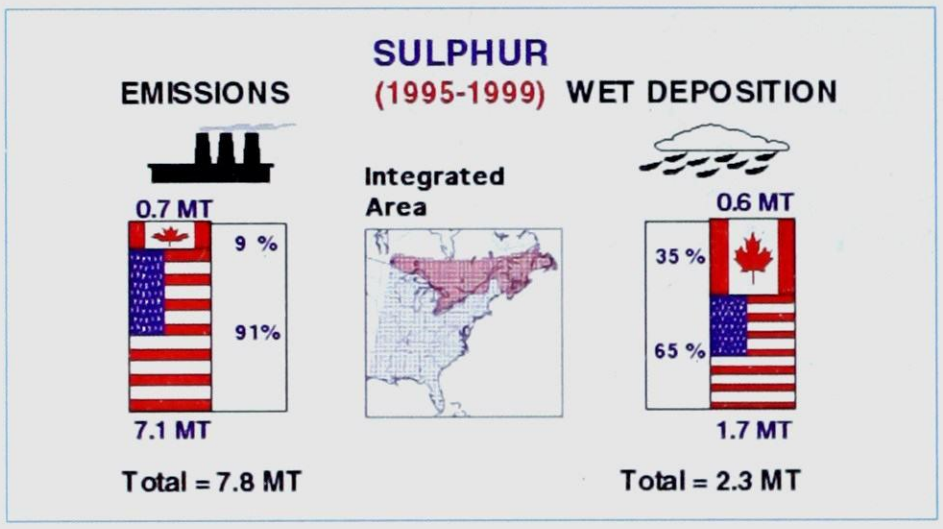


Figure 11 – The relative amounts of SO_2 emissions and $SO_4^=$ wet deposition (as sulphur) in eastern Canada and the eastern U.S. throughout the five year period from 1995 to 1999.

- Dry deposition fluxes of sulphur and nitrogen species were estimated at 12 CAPMoN sites for the period 1998 to 2002. The results were combined with wet deposition measurements to calculate total sulphur and nitrogen deposition and to estimate the relative contribution of wet and dry deposition at each site (see Figure 12). The results are used in the *2004 Canadian Acid Deposition Science Assessment* and by aquatic and forest effects researchers to determine critical load exceedances over eastern Canada.

Acid Deposition Modelling

- **Future-Year Emission Control Scenarios**
  Two new bi-pollutant (SO_2 and NO_x) future-year emission control scenarios were run with the comprehensive Eulerian acid deposition model (ADOM) for year 2020 to support the possibility of a PM Annex to the Canada-US Air Quality Agreement. Results from earlier ADOM scenario runs had contributed to the development of the *Canada-Wide Acid Rain Strategy for Post-2000.* Results of these scenarios are summarized and synthesized in the *2004 Canadian Acid Deposition Science Assessment,* which is due to be released at the end of the 2004 calendar year.
- **Nitrogen Source-Receptors**
  A feasibility study into modelling methods for determining nitrogen source-receptor relationships (SRRs) was also completed, and updated and expanded SRRs for sulphur were delivered to aquatic researchers for use in critical loads determinations.

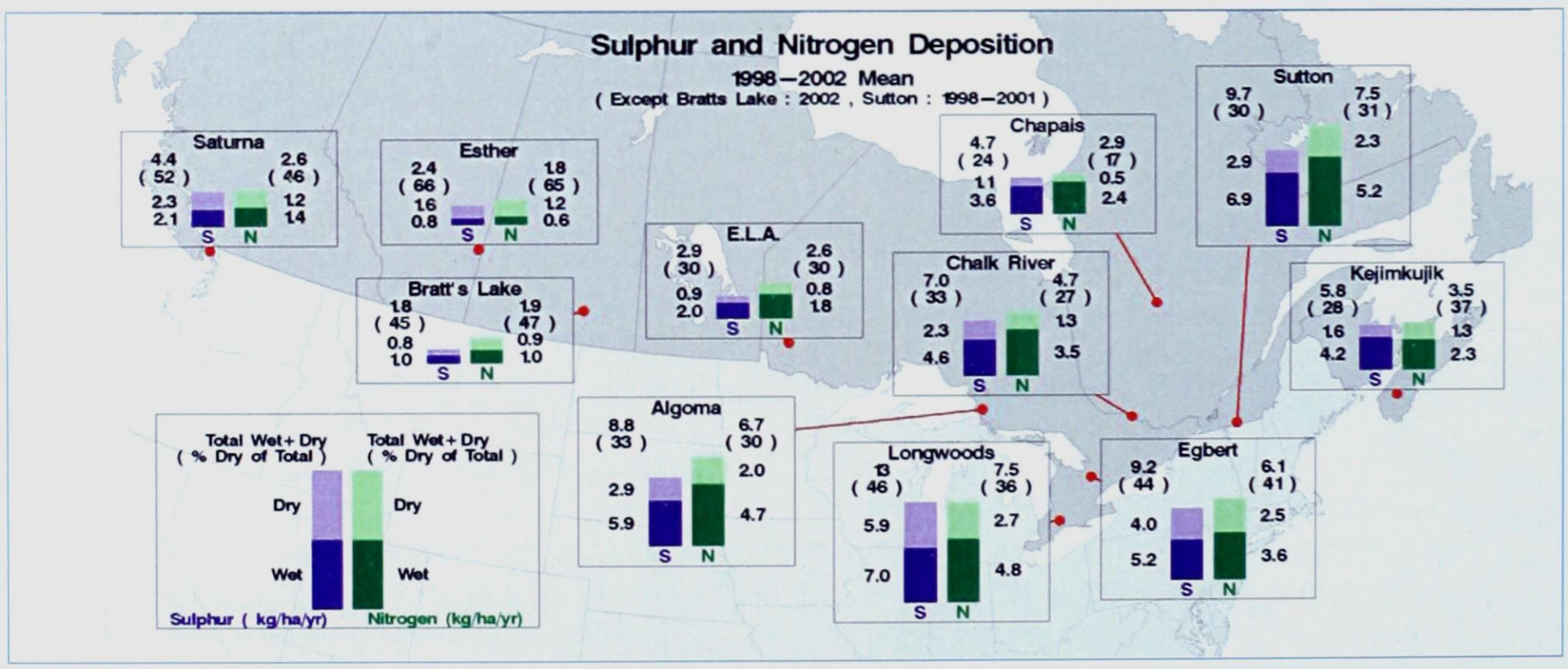


Figure 12 – Wet, dry and total deposition of sulphur and nitrogen at CAPMoN sites.

Hazardous Air Pollutants

The Hazardous Air Pollutants (HAPs) Program meets the information needs of the Great Lakes Water Quality Agreement, the Great Lakes Binational Toxics Strategy; the NAFTA Commission for Environmental Cooperation's North American Regional Action Plans [NARAPs], the Northern Contaminants Program, the Arctic Monitoring and Assessment Program and the United Nations Economic Commission for Europe – European Monitoring & Evaluation Programme (UNECE EMEP).

The Program's overall objective is:

To understand and predict the environmental cycling of air toxics, to provide guidance to the policy community and to reduce risks to human health and the environment.

HAPs-related activity for the 2003/04 fiscal year include: inventory and modelling of persistent organic pollutants, research in the Great Lakes Basin, including research on atmospheric deposition, behaviour of particles and gases, research in the Arctic including temporal trends, mercury studies, and development of passive air sampling.

Global Inventory of Persistent Organic Pollutants (POPs)

- A mass balance box model (the Arctic Mass Balance Box Model – AMBBM) created by AQRB scientists in collaboration with others provided quantitative estimates for the various transport routes for α-HCH to the Arctic. The model pointed to the importance of atmospheric transport during the period 1945-1990. After 1990, ocean currents superseded the atmosphere as the major pathway for α-HCH to enter the Arctic Ocean. The work predicted that complete elimination of α-HCH from Arctic waters would require another two decades.
- The August 15, 2003 issue of *Environmental Science & Technology* featured the work of an AQRB scientist on its cover. The work covered the creation of the global β-HCH (β-hexachlorocyclo-hexane) emission inventories (Figure 13), a critical step in understanding the behaviour of this pesticide isomer and quantifying its concentration in various environmental compartments.

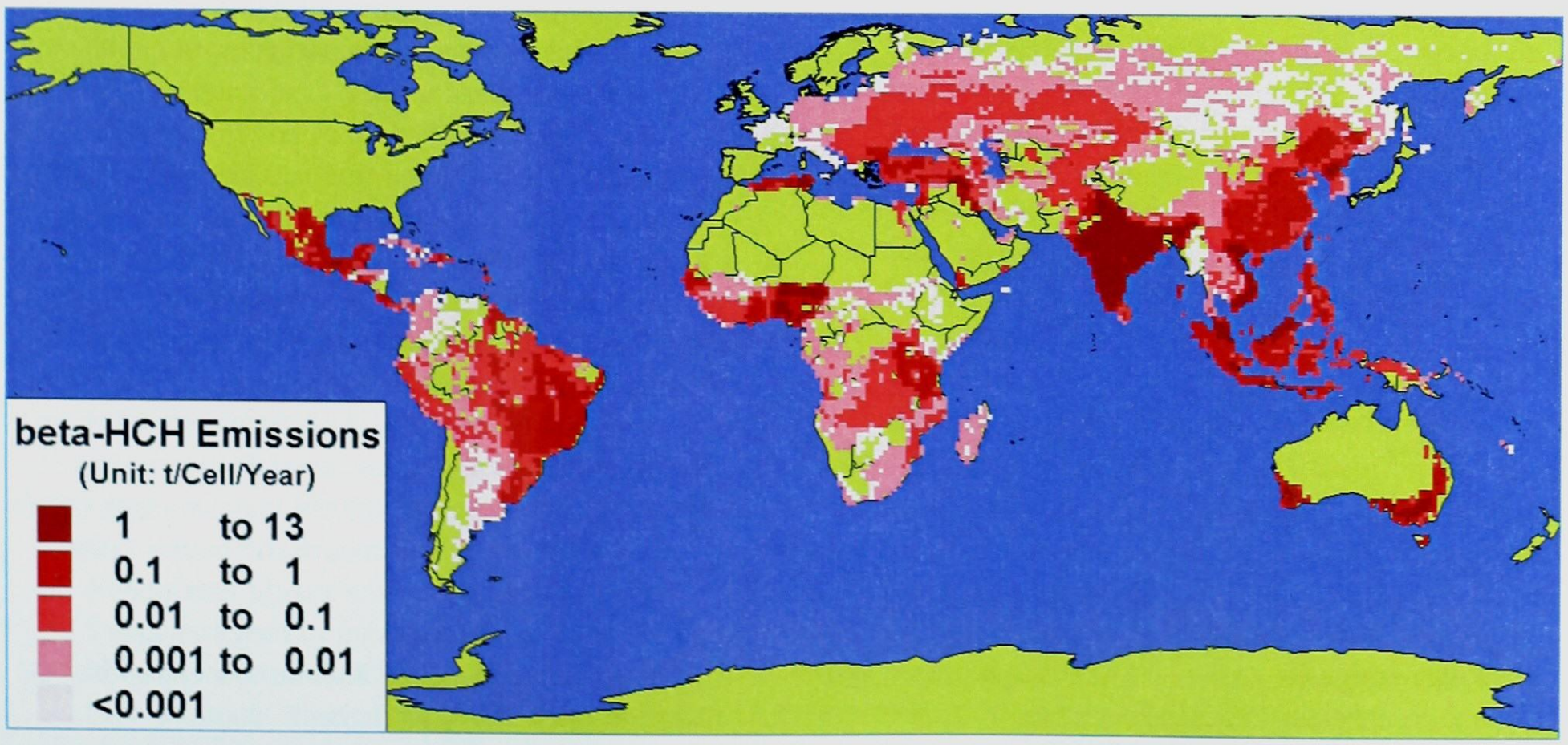


Figure 13 – Gridded global annual emissions for β-HCH in 1990 (Li et al. 2003).

Polychlorinated Biphenyls (PCB) Modelling

Research has been carried out to investigate the emission and fate of semi-volatile persistent organic pollutants (POPs) in the atmosphere, focusing on PCBs and Dichlorodiphenyltrichloroethanes (DDTs). A modelling system CaM/POPs (Canadian Model for POPs) has been developed to simulate the atmospheric pathways of these POPs within the Global Environmental Multiscale (GEM) and Global Climate Model (GCM) frameworks. The preliminary results have been used in the UNECE-EMEP POPs model inter-comparison project in 2003/04. A comprehensive set of simulations have been initiated to study the historical deposition patterns of PCBs in both oceans and soils from the 1930's to the present and to study the future fate of these POPs in the atmosphere.

Canadian Atmospheric Network for Currently Used Pesticides (CANCUP)

The Canadian pesticide air sampling campaign was initiated through funding from the Departmental Pesticide Science Fund (PSF). The purpose was to gather information on the occurrence of currently used pesticides in the Canadian atmosphere. An intensive sampling campaign was carried out over 12 weeks (May-August, 2003) at three sites in the Prairies and over four weeks (July-August, 2003) at five other sampling stations across Canada; these stations are part of the Canadian Atmospheric Network for Currently Used Pesticides (CANCUP).

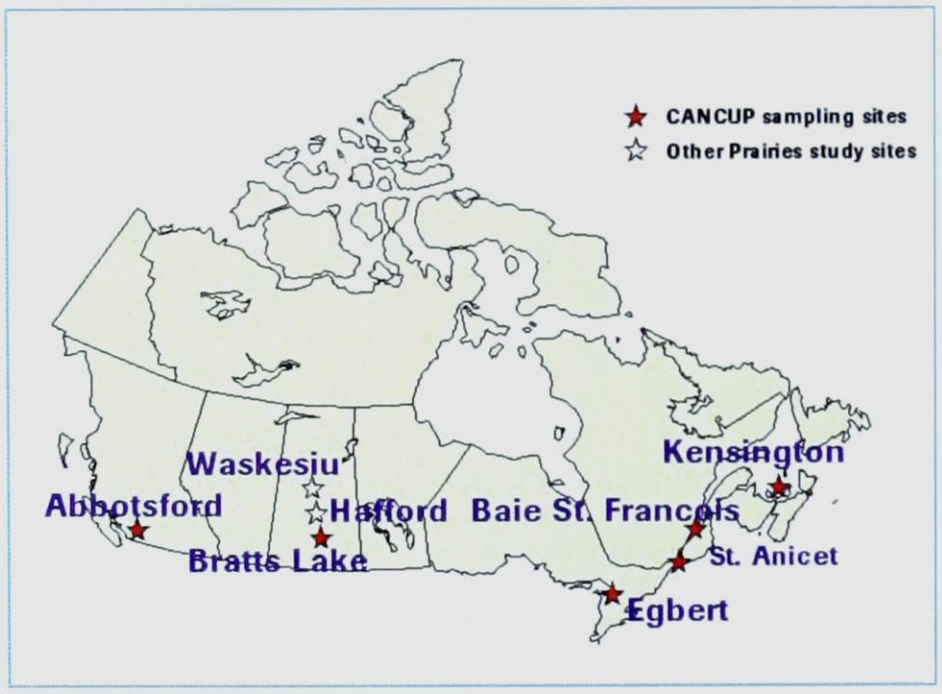


Figure 14 – The Canadian Pesticide Air Sampling Campaign Sampling Sites

Usage/emission inventories will be created for several pesticides – lindane, endosulfan, atrazine, metolachlor, 2,4-D, and chlorophacinone – using the Simplified Gridded Pesticide Emission and Residue Model (SGPERM) for North America. So far usage inventories have been established for atrazine, lindane, and endosulfan in the United States and Canada. This information will greatly contribute to the understanding of the occurrence and fate of these pesticides.

Great Lakes Research

- The Integrated Atmospheric Deposition Network (IADN) is a U.S.-Canada network established to carry out air and precipitation monitoring as outlined in Annex 15 of the Great Lakes Water Quality Agreement to better understand atmospheric deposition of toxic chemicals to the Great Lakes. The Branch oversees IADN activities and carries out research to meet the information needs of the public and Great Lakes policy community. Research activities for the 2003/04 fiscal year are outlined in the following:
- A new loadings report covering years 1999-2000 was prepared. Several improvements were implemented in the model that was used to calculate the loadings. Loading estimates to all the Great Lakes show that loadings of banned pesticides continue to decline while loadings of current-use pesticides show no trend. PCBs are still coming out of the lakes (volatilization) although approaching equilibrium. Combustion by-products such as polycyclic aromatic hydrocarbons (PAHs) and industrial by-products such as metals are depositing to the Great Lakes via precipitation and particle deposition. Data collected in Chicago demonstrated the important contribution of urban centres to the loading of toxic chemicals to the Great Lakes.
- Using a 3-dimensional coupled atmospheric transport model, an investigation was carried out to study the atmospheric transport of lindane to the Great Lakes from the canola fields in the Canadian Prairie Provinces and from corn fields in southern Ontario and Quebec. The model results indicated that despite the close proximity to the Great Lakes, lindane usage in Ontario and Quebec has only minimal effects on the air concentrations measured in the Great Lakes region compared to that in the Prairies. Two main factors influencing these results are: (i) lindane application regions in Ontario and Quebec are generally downwind of the Great Lakes, and (ii) the lindane usage rate for canola is nearly ten times that for corn. Long range transport from the Prairie Provinces is the major factor contributing to increases and seasonal variations of lindane concentrations and loadings to the Great Lakes.

- From September 2002 to March 2004, air samplers from Germany were installed at Point Petre to measure combustion by-products such as PAHs. This study has resulted in a link between the U.S.-Canadian IADN and the major POP network in Europe (EMEP). Several MSC scientists will travel to Germany in July 2004 for a data workshop. This will be followed by a modelling exercise led by the Meteorological Synthesizing Centre East (MSC-E) in Moscow.
- IADN data have been used to describe particle/gas partitioning of PAHs. Results show that the extent of partitioning is only partially explained by atmospheric temperature (which drives PAH volatility). Differences in partitioning between network sites are significant, with greater amounts of PAHs associated with particles in less polluted areas. Such results further our ability to predict the fate of PAHs in the environment.
- In the 2003/04 fiscal year, air sampling at the Lake Ontario Buoy in western Lake Ontario and the IADN master station at Point Petre, Ontario was co-ordinated with measurements made by American collaborators on the lake using the vessel known as the Lake Guardian. Sampling was also done at a land-based site at Sterling, NY as part of the Lake Ontario Atmospheric Deposition Study (LOADS). Results will be used to achieve a mass balance estimate for POPs and mercury for Lake Ontario.

Research in the Arctic

- As part of the Northern Contaminants Program (NCP), regular ground level atmospheric measurements of 126 organochlorine compounds (OCs) (including PCB congeners, toxaphene, chlordane, DDT, chlorobenzenes, selected pesticides and industrial chemicals) and 20 selected polychlorinated aromatic hydrocarbons (PAHs) were continued at the Canadian High Arctic site of Alert, Nunavut. The chemical list has been revised to include the measurement of 14 polybrominated diphenyl ethers (PBDEs), endosulfan II and 2 methylnaphthalenes. These compounds are of growing international concern and are, or may be, impacting the Arctic environment.
- Temporal trends of organochlorine pesticides and PCBs in the Canadian Arctic atmosphere have been evaluated (Figure 15). Evidence was found

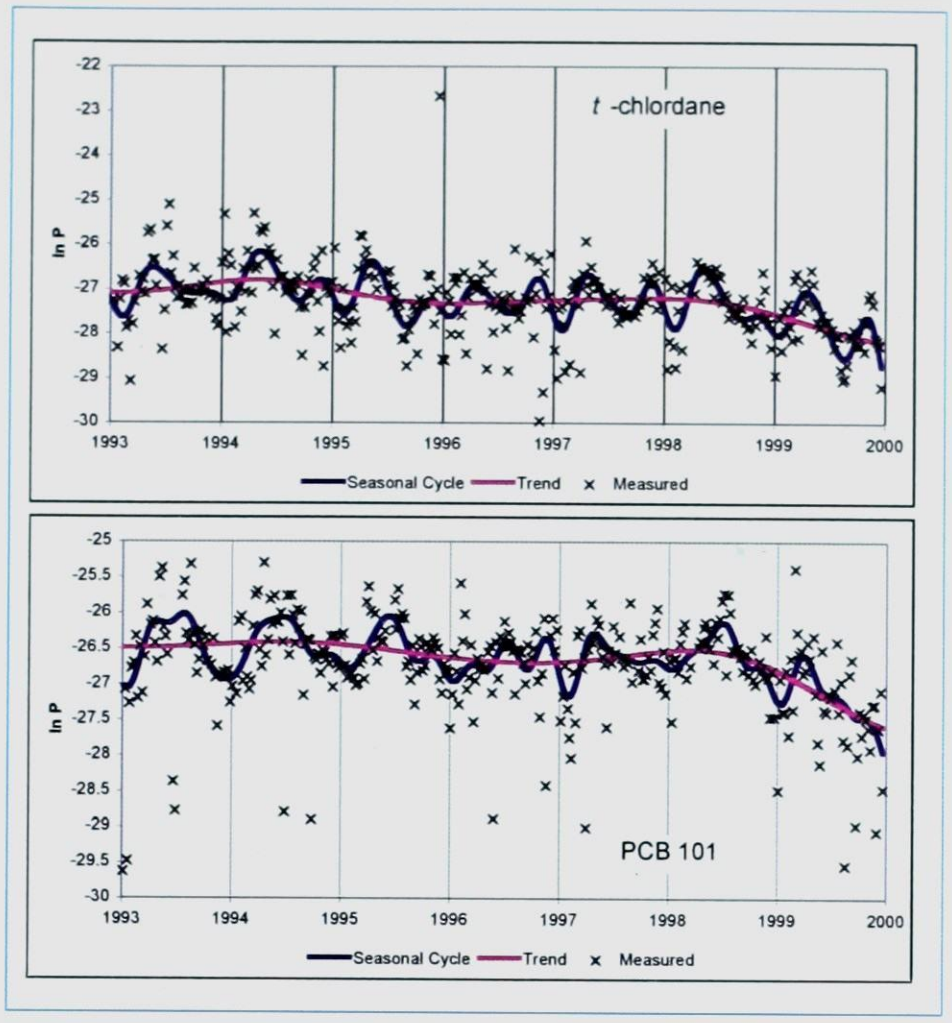


Figure 15 – Declining air concentrations of (a) *t*-chlordane and (b) PCB 101 measured at Alert in the Canadian High Arctic (y-axes expressed as the natural log of partial pressure in air, P)

linking climate fluctuations with the POP levels in North America. The air concentrations of POPs measured from 1990 to 2000 in the Great Lakes region and at Alert were compared over the same time period to North American surface air temperatures and indices that reflect the strength of three atmospheric circulation patterns: the North Atlantic Oscillation (NAO), the El Niño-Southern Oscillation (ENSO) and the Pacific North American (PNA) pattern. These are the same climate fluctuation patterns that bring warmer or cooler than normal winters/springs to western and central North America. Organochlorine (OC) and PCB air concentrations at Alert were found to be influenced by two climate variation patterns, the NAO and the PNA patterns. Wind flow patterns associated with the PNA may be an important mechanism for enhancing the transport of pollutants to the Arctic. Findings from the air monitoring of POPs in the Arctic since 1998 were summarized in the Canadian Arctic Contaminants Assessment Report II (CACARII).

POPs in the Ambient Air of Mexico

Organochlorines in the air of Chiapas, southern Mexico were surveyed during 2000-2003 at a suburban site in Tapachula (TP) and an organic coffee plantation in the

mountains (MT), about 40 km from Tapachula at an elevation of 1200-1400 m. Air samples were collected using active and passive samplers (based on technology developed by an AQRB scientist). Higher concentrations of DDTs and increased proportions of DDT/DDE were found at MT than TP. Soil samples collected near the two sites also showed higher DDT/DDE at MT. The predominance of "fresh" DDT at MT suggests continued (illegal) usage and/or regional-scale air transport from neighbouring Central American countries. Toxaphene concentrations in air were higher at TP than MT. Depletion of labile congeners in the toxaphene profiles of air and soils suggested that emissions from soil rather than current usage were responsible for the toxaphene found in air. Studies are undertaken in Mexico to understand its potential as a source region to Canada and its contribution in a North American context.

Passive Air Samplers

- **Technology**
  Passive air samplers (Figure 16) were demonstrated to provide a simple, cost-effective and logistically feasible means for assessing air concentrations at regional, continental and global scales. A network was established which encompasses over 20 sites in the Great Lakes basin, including the IADN master stations and satellite sites, three remote sites in Canada (Nunavut, Yukon, B.C.), Mexico, Chile and South Africa. This technology, developed at MSC, has also been shared with collaborators at Lancaster University in the U.K. who conducted a European sampling campaign at over 50 sites across Europe. These advances in the area of passive air sampling put Canada in a leading position for addressing various monitoring and research obligations outlined under the Stockholm Convention on POPs under the United Nations Environment Programme (UNEP).
- **Passive Air Sampling in Arctic Air**
  A project was initiated to design and develop a passive air sampling device suitable for use under Arctic conditions. This new design will be used to supplement or replace active air sampling in future Arctic air monitoring network(s), and to increase spatial definition of POP air concentrations in the Arctic. Such monitoring programs would gather POP air concentration data in support of the Long Range Transboundary Air Pollution (LRTAP) and Stockholm conventions.

Figure 16 – PUF–Disk Passive Air Sampling Device

Laboratory Work

- **Henry's Law Constants and Air/Water Exchange of Chlordanes**
  Chlordanes, *p,p'*-DDE and hexachlorobenzene (HCB) are abundant organochlorine pesticides in Great Lakes and Arctic ecosystems and the Henry's Law constant (Pa m^3 mol^{-1}) is a critical factor in describing their partitioning between air and water. The Henry's Law constants for *trans*- and *cis*-chlordane, *trans*-nonachlor, HCB and *p,p'*-DDE were determined by the gas stripping method over a temperature range of 5 to 35 °C. The temperature-dependent Henry's law constants were applied to assessing the air-water gas exchange of chlordanes and *p,p'*-DDT in Lake Ontario for a set of air and water measurements made in 1998. Results indicated that these chemicals were undergoing net volatilization during that time. These constants will also help improve loading estimates for chlordanes and *p,p'*-DDE in the IADN program.

Emerging Chemicals

Three classes of persistent organic pollutants considered part of the emerging chemicals of interest for future controls – brominated flame retardants (e.g. PBDEs), fluorinated surfactants (e.g. PFOS precursors) and poly-chlorinated naphthalenes (PCNs) have been studied in the 2003/04 fiscal year. Analytical methods have been developed for measuring PBDEs and PFOS precursor compounds in air and used to identify a large indoor/outdoor air gradient. The first intercalibration study (9 participating labs from 7 countries) for PCNs was completed and results were published. The results will be useful to modellers and chemical assessment/regulatory groups.

Mercury Studies

- **Gaseous Elemental Mercury Observations**
  The Branch is highly involved in the measurement and assessment of atmospheric mercury. The first calculation of atmospheric mercury in the atmosphere, based on measurements to 7 km altitude, was published in the 2003/04 fiscal year. It was shown that the seasonal variation in gaseous elemental mercury (GEM) observed at mid-latitude Canadian sites is seen throughout the troposphere and is not confined within the boundary layer on a local or regional scale. Thus the reason for this seasonal variation must be sought on a larger scale than previously thought. The results demonstrate the existence of a vast pool of mercury aloft which can be drawn down to the Earth's surface by atmospheric mixing processes even in remote regions of the world. These results also provide information needed for the interpretation of the cycling of mercury globally.
- **Field Campaign: Mercury in the Arctic**
  Research continues into understanding the process and impact of atmospheric mercury depletions (MDEs) in the springtime. Gaining more insight into the distribution of different species of mercury under various conditions during MDEs will aid in understanding the impact these events may have on the surrounding environment. During April 2003, an international inter-comparison and processes field campaign was held in Ny- Ålesund, Svalbard where experts in the mercury community from six different countries combined knowledge and instrumentation to further understand mercury depletion events in the Arctic. Inter-comparative results indicate that while gaseous elemental mercury (GEM) measurements compare well, current reactive gaseous mercury (RGM) and particulate-phase (e.g. PM) methodologies compared poorly.

An additional international inter-comparison and processes study, involving scientists from four different countries, followed in Barrow, Alaska in March 2004. This study focussed on improving measurement methodologies, applying lessons learned in Ny- Ålesund to Barrow. Continuous measurements of total atmospheric mercury and mercury species were undertaken by automated methods. In addition, for shorter time periods within the study, particulate and reactive gaseous mercury species were measured by manual methods and profiles of GEM from within the snowpack to 10 m above the snow surface. This campaign focused on the behaviour of mercury during the day and night period of spring as well as during the snow melt. Results from this campaign are forthcoming.

Mercury Modelling

The GRAHM (Global/Regional Atmospheric Heavy Metals Model) was integrated to evaluate the source receptor relationships for various regions around the globe. Model estimates of source contributions of mercury to Canada and the Great Lakes region from global sources were provided to the Environmental Protection Service of Environment Canada and many others for policy applications. Simulations for the second stage of the UNECE Environmental Monitoring and Assessment Program (EMAP) inter-comparison study were completed. Results were submitted to the Meteorological Synthesizing Centre East (MSC-E Moscow) and contribution was made to the final report on the inter-comparison study. Processes in the air and at the surface related to the spring time depletion events in the Arctic were developed and included in the GRAHM model. An article on Arctic mercury cycling has been accepted for publication in Tellus and another on the model description and global cycling of mercury was published in a 2004 issue of Atmospheric Environment.

Greenhouse Gases & Aerosols

The Greenhouse Gases (GHGs) and Aerosols Program's overall objective is:

To contribute to the understanding of greenhouse gases (and their isotopes) 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.

In the 2003/04 fiscal year, a number of greenhouse gases and isotopes measurements were taken and several aerosol studies were carried out under the Greenhouse Gases and Aerosols Program.

Greenhouse Gases and Isotope Measurements

MSC currently operates a small network of stations strategically located to reflect the regional sources/sinks distribution and long-range transport of GHGs into and out of Canada (Figure 17).

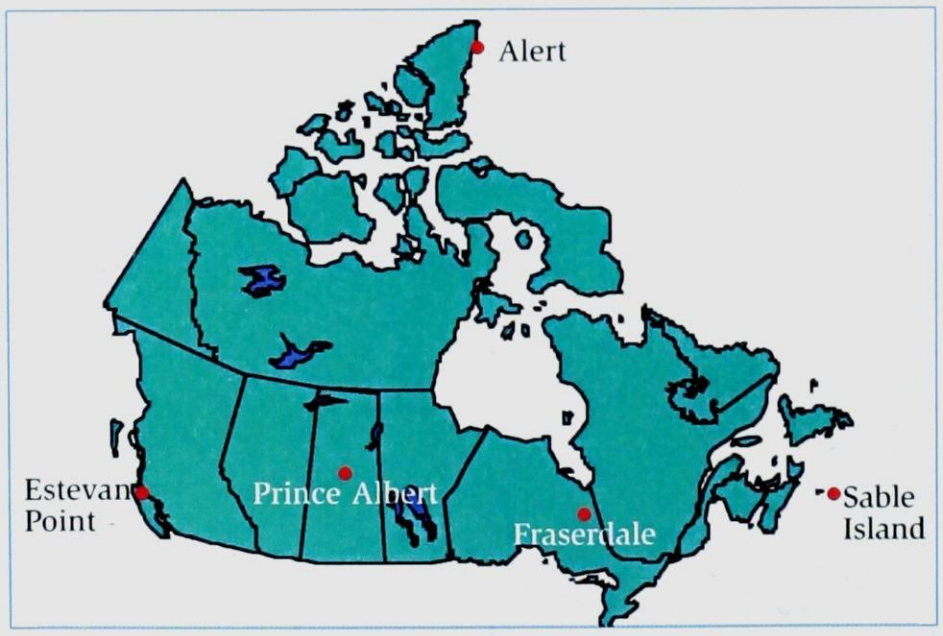


Figure 17 – Location of Canadian Baseline Sites

These atmospheric monitoring activities are research-oriented rather than routine, and provide the scientific and policy-making communities with high quality GHG and CO_2 isotope data. These measurements also constitute Canada's contribution to the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) Program. Some new initiatives and accomplishments over the 2003/04 fiscal year include:

- **Participation in the *CO_2 Budget and Regional Airborne Study: North America 2003* (COBRA-NA2003)**
  Scientists from the AQRB participated in the COBRA-NA2003 study. The study was led by Harvard University with participation from the National Oceanic & Atmospheric Administration (NOAA), the National Center for Atmospheric Research (NCAR) and Fluxnet Canada. The primary objective of the COBRA study was to test concepts associated with the North American Carbon Program, including data assimilation studies to estimate large scale sources and sinks of greenhouse gases and ozone-destroying compounds within the North American continent. MSC's role involved coordination of ground flask sampling with the COBRA aircraft as it passed over the Canadian observational sites. All corresponding data can be found in the COBRA database which is available for use by all participants at the following website: www.fas.harvard.edu/~cobra/.
- **Continuous Measurements of GHGs, Aerosols and Isotopes**
  In June 2003, continuous measurements of CO_2, CH_4, CO, N_2O and SF_6 began at Sable Island, as part of the Sable Island Airshed Monitoring program, which also includes the additional measurements of NO_x, SO_2/H_2S, ozone and $PM_{2.5}$. The continuous measurements will aid in adequately capturing the level of seasonal metabolic activity originating from the North American continent. In addition, the analysis of

stable isotopes ($^{13}C/^{12}C$ and $^{18}O/^{16}O$) in CO_2 from the weekly flask samples was initiated in order to help partition the terrestrial and anthropogenic carbon signals.

- **Installation of an Automated Flask Sampling System**
  An automated flask sampling system was designed, built and installed at Fraserdale for long-term diurnal trend analysis for GHGs and CO_2 isotopes. Diurnal sampling (two samples taken, one at night when the concentration of CO_2 is at its maximum and one during the day) will provide information on biospheric signals from various ecosystems as well as on the individual processes of photosynthesis and respiration. Such information will eventually prove to be crucial in constraining regional sources and sinks of CO_2 and in evaluating the importance of regional terrestrial ecosystems within the global carbon cycle. The concepts of the program were presented at the NOAA/Climate Monitoring & Diagnostics Laboratory (CMDL) Annual Meeting in May 2003.
- **Flask-Diurnal Sampling Campaign**
  A comparison of CO_2 and its isotopes from eight intensive (sampling every two hours) flask-diurnal sampling campaigns conducted between 1998 and 2000 with background values derived from NOAA/CMDL cooperative flask network showed that ecosystem processes play an important role in seasonal variations of background-air. The variations were primarily caused by biospheric signals propagating from the atmospheric boundary layer to the free troposphere and then upward to the Marine Boundary Layer. This work was presented at the American Geophysical Union (AGU) Fall meeting in 2003. Interest in the findings resulted in a proposal to the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) in collaboration with the University of Toronto on regional carbon source and sink estimate studies.
- **Host of a WMO/IAEA Expert Meeting**
  Scientists in the AQRB successfully organized the 12th WMO/ International Atomic Energy Agency (IAEA) Expert Meeting of CO_2 and Related Tracer Measurement Techniques in September 2003. Sixty delegates and scientists from 16 different nations participated at the meeting. The purpose of the meeting was to ensure that protocols for the measurement and reporting of CO_2 data were being adhered to and to provide a forum for discussing recent developments, improvements, and issues. Recommendations on procedures and actions in order to achieve adopted WMO goals for global network comparability for various components were agreed upon and will be published in an upcoming WMO meeting report.

Aerosols

- **Canadian Surface Ocean and Lower Atmosphere Study (C-SOLAS)**
  The Air Quality Research Branch participated in the Canadian C-SOLAS cruise in the northeast Pacific Ocean during July 2002 and conducted aircraft measurements during the October 2003 western Atlantic cruise. The main objective of this study was to understand the impact of biogeochemical trace gases on the chemical and physical properties of atmospheric particulate matter.

  Figure 18 shows an example of the time series of particulate sulphate (SO4) and methane-sulphonic acid (MSA) measured during the 27 day campaign. In the marine environment, MSA and sulphate are determined largely from the oxidation of dimethyl sulphide (DMS) emitted from organisms in the surface layer of the ocean.

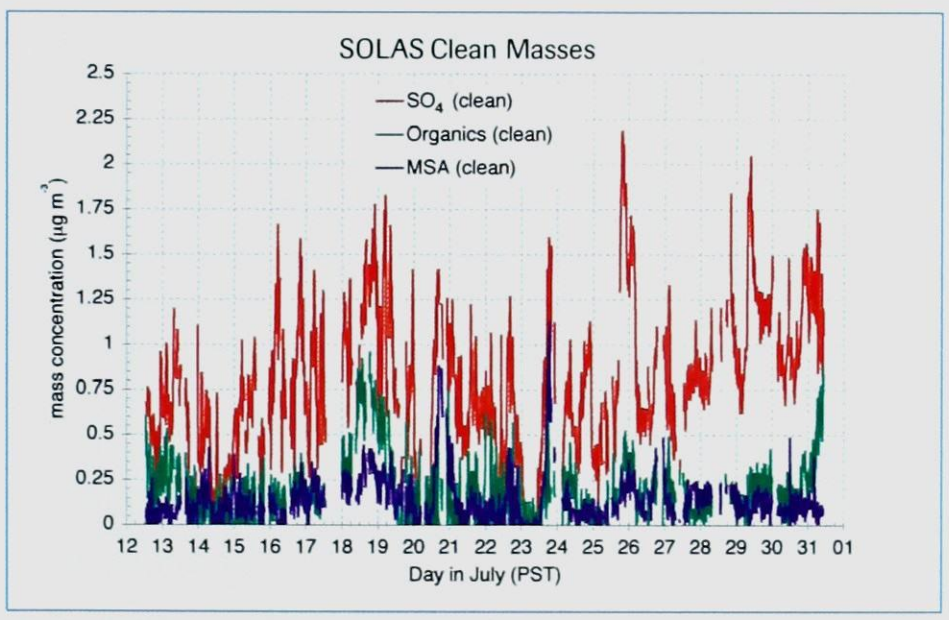


Figure 18 – Time Series of Particulate SO_4 and MSA

- **Arctic Aerosols**
  Measurement of Arctic aerosol chemistry was continued during the 2003/04 fiscal year to support the Canadian Baseline Program. The focus of this project was to monitor recent trends of various aerosols at the Arctic station. Findings showed a declining trend of sulphate since 1990 which levelled off and is now starting

to increase (Figure 19). These results may be a reflection of two important factors influencing the concentration of Arctic aerosols over the last 15 years. The first is the emission inventory of sulphate which may have started to recover due to the collapse of the former Soviet Union and subsequent closure of many polluting industries. The other factor is Arctic oscillation that may have started to shift the circulation pattern to the Arctic from more polluted areas.

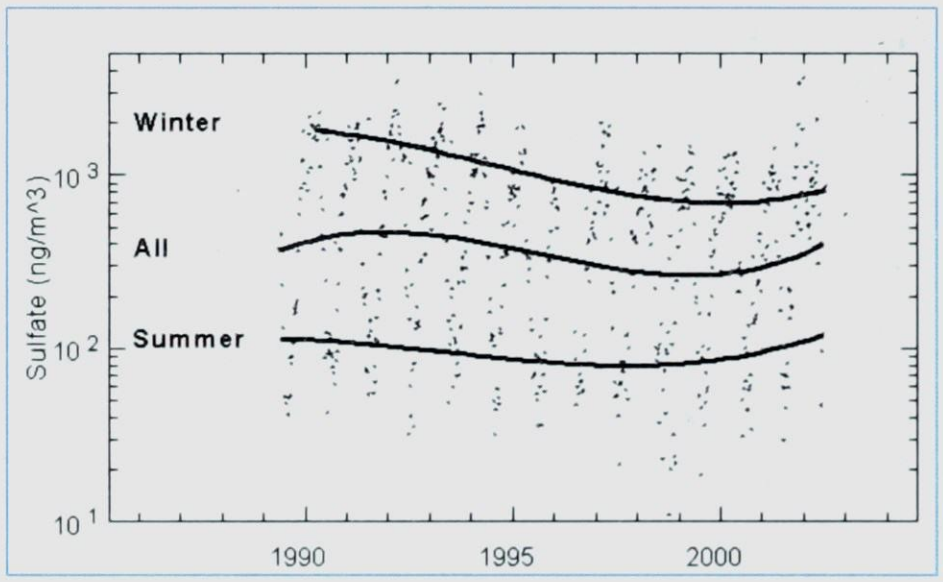


Figure 19 – Trend Analyses of SO_4 in the Arctic Air

- **Aerosol Light Extinction at Alert**
  In response to growing concerns about the role of aerosols in climate change issues, aerosol researchers at MSC and NOAA are collaborating to enhance the existing aerosol program at Alert. Two new instruments were deployed at Alert during March 2004. A 3-wavelength nephelometer (MSC's contribution) was installed to measure the aerosol light scattering along with a condensation particle counter (CPC, NOAA's contribution) to measure particle concentration. Along with these instruments, a Particle Soot Absorption Photometer (PSAP) has been used to measure light absorption by particles since 1998. An impactor system for delivering size-segregated (1 and 10 µm) samples to PSAP and nephelometer will be implemented towards the end of the 2004/05 fiscal year. The data from all three instruments are available for viewing at http://www.cmdl.noaa.gov/aero/net/alt/index.html.

- **Time Series of Black Carbon (BC) Concentrations**
  The time series of black carbon (BC) concentrations from 1989-2002 at Alert indicates a downward trend over the past 12 years and shows a decrease in concentrations of more than 50% (Figure 20). This decreasing trend is also suspected to be a result of reduced emissions from the regions incorporating the former Soviet Union.

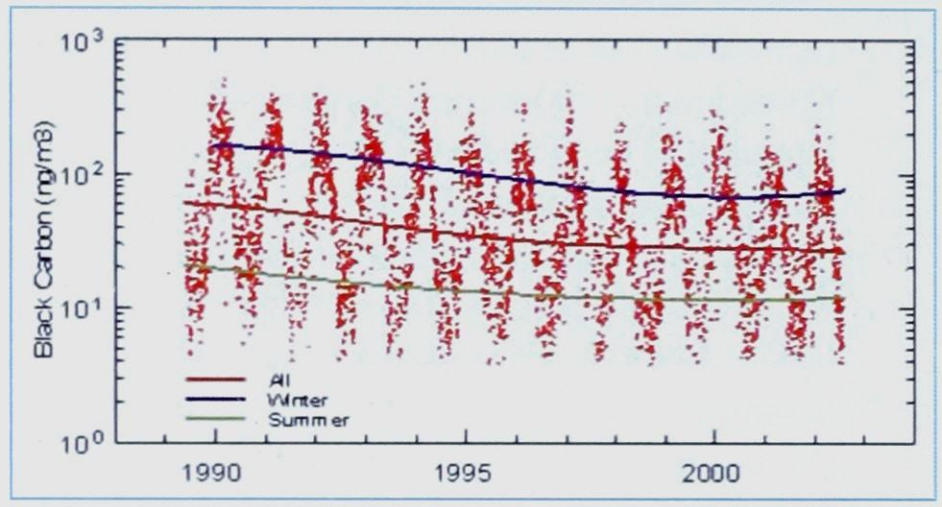


Figure 20 – Time Series of Black Carbon Concentrations

Stratospheric Ozone

The Stratospheric Ozone Research Program's overall objective is:

To determine the behaviour of radiatively active species, including gases and aerosol particles, in the free troposphere and stratosphere.

The AQRB Stratospheric Research Program has historically been involved in observing changes in the stratospheric ozone layer, including the chemistry of ozone production and destruction. The expertise developed over the years from these efforts has broadened to include surface observations, the design of satellite instrumentation and the analysis of the distribution of ozone and UV in both time and space. Achievement highlights for the 2003/04 fiscal year include:

UV and Stratospheric Ozone

- **Aerosol Optical Depth Measurements**
  In late 2003 a new algorithm for deriving Aerosol Optical Depth (AOD) from Brewer UV measurements was implemented. This will feed important information about airborne particulates into air quality forecast models currently being developed in ARQB.
- **Addition of New Ozonesonde Network Sites**
  Four new Ozonesonde Network sites were added in southern Canada in order to study differences in tropospheric ozone, and the importance of stratospheric and free tropospheric ozone to surface ozone levels. These new sites, along with the six older sites, will also provide vital information for air quality forecast models.
- **Monitoring Surface UV and Ozone**
  The monitoring of surface UV and ozone continues to provide Canadians with up-to-date information required for accurate forecasts of the UV index. The ground-based data used in the 2002 United Nations Environment Programme (UNEP) and WMO Scientific Assessment of Ozone were obtained from the World Ozone and UV Data Centre (WOUDC) – see

Figure 21. Scientists from the AQRB participated in this assessment and in the Arctic Council/ International Arctic Science Committee *Arctic Climate Impact Assessment* (2004), by authoring and reviewing the scientific content.

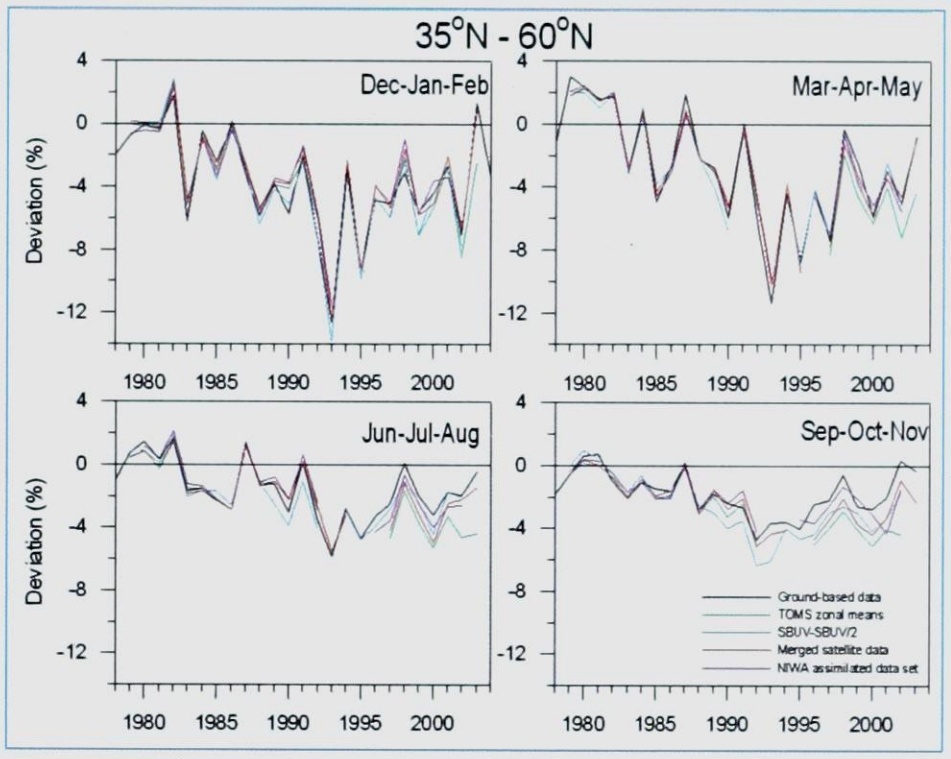


Figure 21 – Seasonal area weighted total ozone deviations from the pre-1980 level in percent for the 35°-60°N belt estimated from five data sets (updated from WMO ozone assessment – 2002)

- **Ozone Observation Using Remote Sensing Technologies**
  One major project undertaken in the last year was the observation of ozone related compounds during the Atmospheric Chemistry Experiment (ACE) Arctic Validation Campaign at the Canadian Arctic Stratospheric Ozone Observatory (ASTRO) at Eureka, Northwest Territories. Another was the completion of a spectrometer for the measurement of atmospheric chemistry aboard the Canadian satellite SCISAT-1. In August 2003, the instrument named, MAESTRO, for "Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation" was launched aboard the Canadian SCISAT-1 satellite and is taking measurements to help understand the chemical processes involved in ozone depletion. The excellent ozone depletion data returned by the instrument will allow scientists to gain a better understanding of ozone chemistry in the stratosphere.

Figure 22 – Pre-launch preparations of the MAESTRO satellite instrument at the University of Toronto by lead scientist Dr. C.T. McElroy

Over the last several years, scientists have built a small satellite spectrometer capable of measuring sunlight in the UV, visible and near-infrared portion of the solar spectrum. From these observations, information about atmospheric aerosols, ozone, nitrogen dioxide and other gases can be retrieved.

Figure 23 – SCISAT-1 Satellite

Radiation

- To build on the 2002-03 development of test and calibration instrumentation, the National Atmospheric Radiation Centre (NARC) began commercial calibration of charge-coupled device (CCD) array spectrometers. Interest in these CCD-type instruments by Natural Resources Canada for characterizing photovoltaic (PV) panels has led to a collaborative effort to build an operational instrument for the measurement of spectral global, direct and diffuse irradiance. Development will continue through 2004-05 with a projected deployment of between two and four instruments in 2005/06. During the last quarter of 2003/04, the International Energy Agency (IEA) recognized the need for spectral observations with respect to a new International Standards Organization (ISO) technical standard for PV in a newly defined task. These national and international collaborations will enable NARC to move forward in developing operational instrumentation for spectral observations that will aid in understanding photochemical processes.
- During the summer of 2003, a collaborative research project with Simon Fraser University was undertaken to observe spectral irradiance using a double-monochromator scanning spectrometer. During the time of the observations (Figures 24 to 27), the Kelowna fires were active, reducing visibility and altering the spectral distribution of the surface irradiance. The magnitude of these forest fires over the Regina, Saskatchewan area can be visualized by changes in the Aerosol Optical Depth (AOD), which represents the amount of attenuation through the atmosphere caused by atmospheric particulates. The optical properties of aerosols, specifically how much sunlight they scatter and absorb is useful data that can be combined with satellite data in atmospheric computer models to provide a more comprehensive air quality forecast.

Observation of Increased Atmospheric Particulates from the Kelowna Fire Over the Regina, Saskatchewan Area September 5, 2003

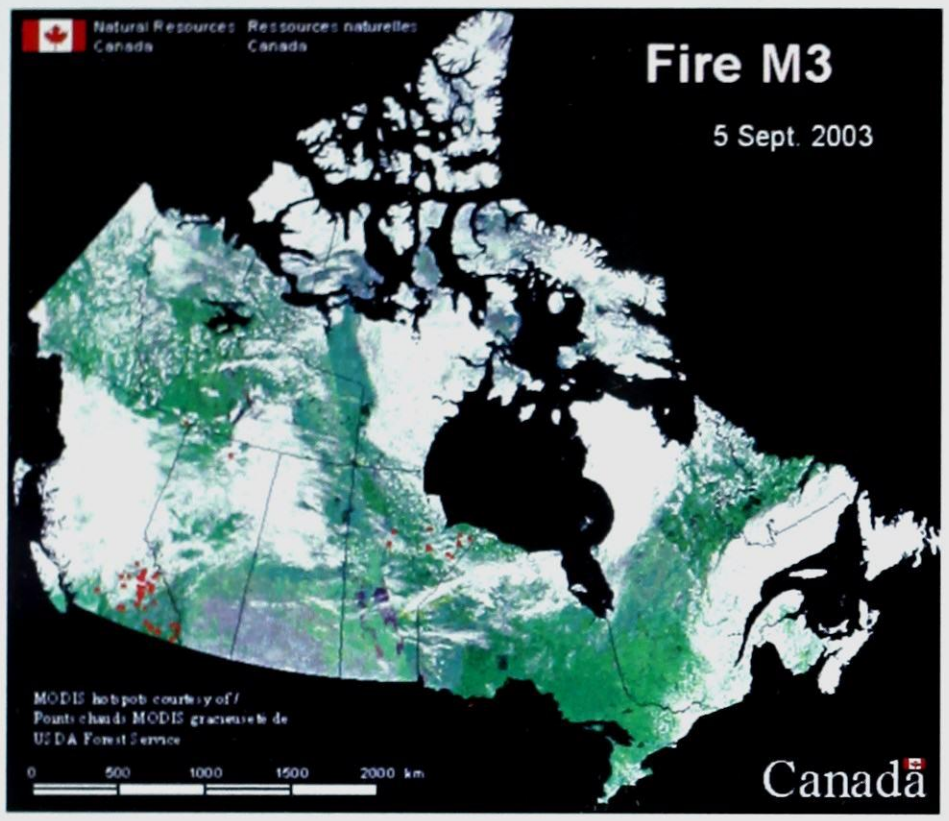


Figure 24 – This panel shows the areas where fires were active at the time.

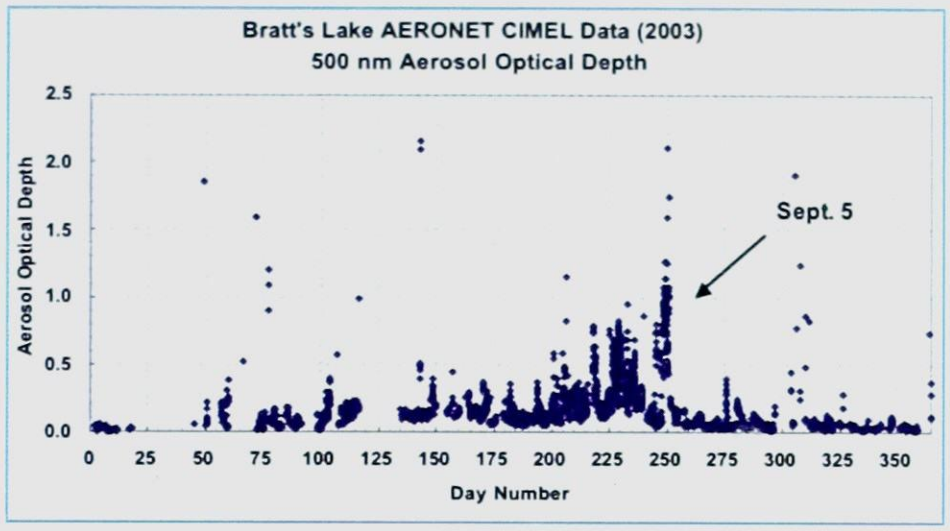


Figure 25 – This diagram illustrates the increase in the aerosol optical depth for September 5, 2003.

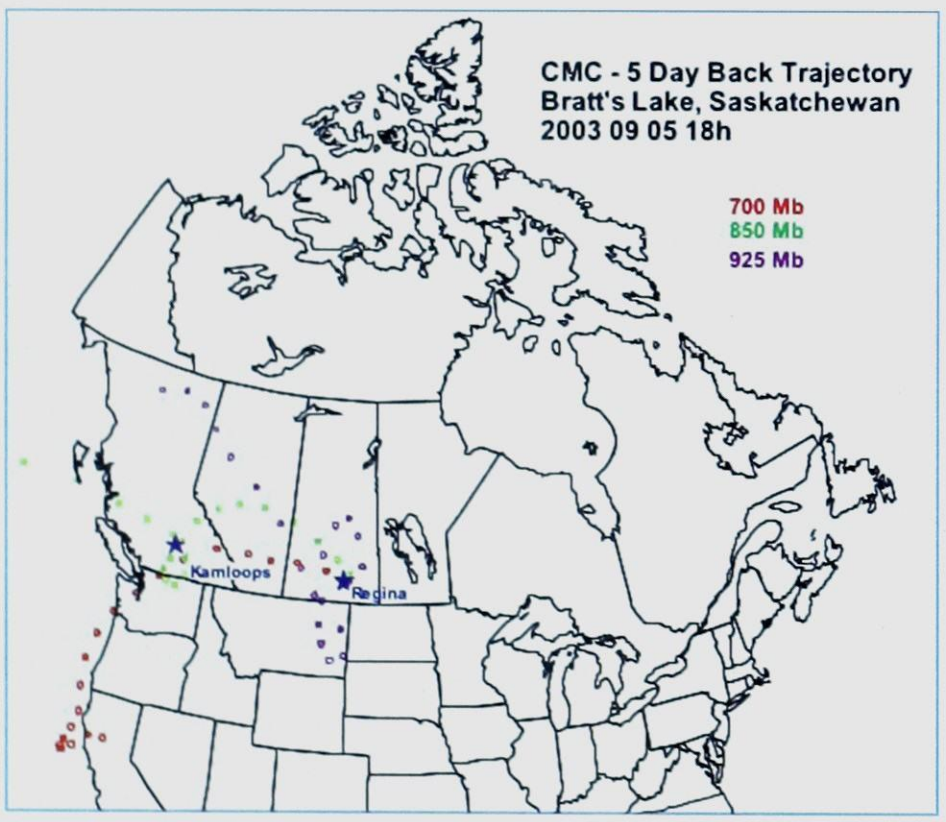
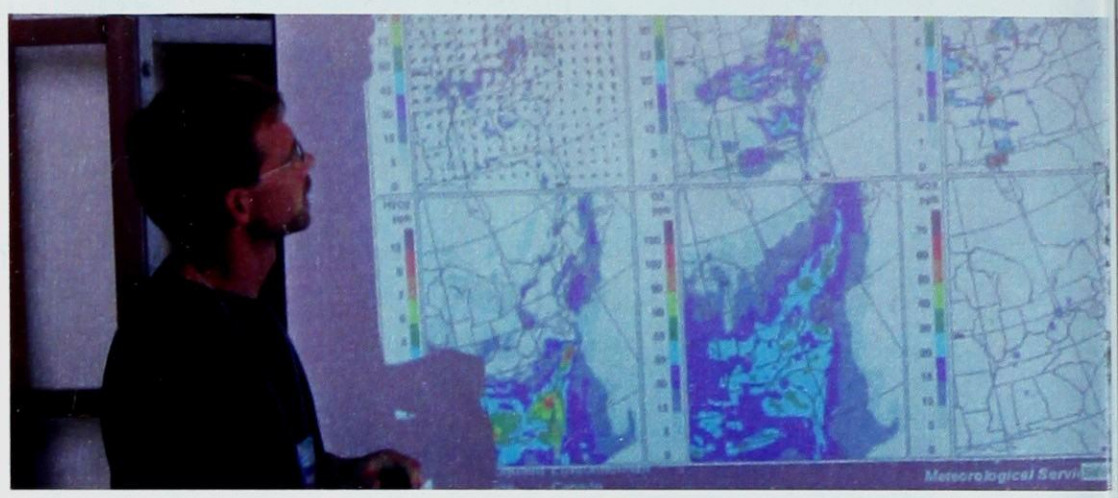


Figure 26 – Using analyses of back-trajectories provided by the Canadian Meteorological Centre, one can see that the air in the lower free troposphere travelled from the Kelowna area to Bratt's Lake.

Figure 27 – Image of the Cimel sunphotometer that measures aerosol optical depth with its satellite antenna to the left by which it transmits data to NASA via the Geostationary Operational Environmental Satellite (GOES).

Air Quality Predictions and Model Applications



The overall objective of the Air Quality Predictions and Model Applications Group's function is:

To provide timely air quality forecast services to Canadians by combining real-time meteorological forecast models with real-time air quality models.

The AQRB modelling group in collaboration with the Canadian Meteorological Centre (CMC) is continually improving the suite of air quality models and is developing scenarios to help determine the significance and impact of emissions to the atmosphere. This work provides fundamental information to support air quality management and policy decisions. Achievements over the 2003/04 fiscal year are listed below:

- Over the past year, the collaboration between the AQRB and the CMC has strengthened and the benefits of the newly formed Air Quality Models Application Group (AQMAG) are becoming more evident. For instance, the Group's work has enhanced the MSC's ability to provide timely air quality forecast services to Canadians.
- An experimental real-time forecast version of AURAMS was implemented at CMC in summer 2003 by the AQMAG. This version was run daily for several months to forecast PM concentration fields, including predictions in September 2003 of the air-quality impacts of hurricanes Isabel and Juan.
- A new emissions processing system for air quality models has been installed by AQMAG at CMC as part of a collaborative effort with AQRB, CMC, and the National Research Council in Ottawa. Work is underway to use this new system to create emissions files for use by AURAMS and other MSC air quality models. This system will also allow for better cooperation and exchange of emissions data between MSC and other modelling groups in Canada, the U.S., and elsewhere.
- Experimental CHRONOS runs for testing the Canada-Wide Standards (CWS) Guidance Document were done based on emission scenario runs for Ontario, Quebec and the U.S. and a strategy for streamlining emissions processing systems is underway along with real-time comparisons between AURAMS and CHRONOS.

Web Access to Modelling Data

The AQMAG is increasing public access to modelling data. For instance, operational CHRONOS runs are made available through the web and plans to expand the suite of online modelling data are underway. Real-time air quality information is also available on the U.S. Environment Protection Agency's (EPA) AIRNow website (http://www.epa.gov/airnow/canada/). These efforts help increase the accessibility to air quality information allowing Canadians to make informed decisions to reduce air pollution and protect their health.

Working with Others

The AQRB works with a number of partners at the directorate, regional, departmental, provincial, national and international levels. A number of R &D activities are carried out in collaboration with universities and other research institutes. AQRB's research contributes to national and international policies on air quality. The following section highlights examples of collaboration on research efforts.

- Progress was made on two collaborative projects with Environment Canada regional offices on emissions processing for the AURAMS western domain in the 2003/04 fiscal year. A biogenic emissions database was constructed at a 1 km resolution for the Canadian side of the Georgia Basin, using forestry data obtained from the British Columbia government. In the next fiscal year, this new database will be used to generate biogenic hydrocarbon emissions in air quality models for regional (PYR) and national applications. Emissions speciation files were created and tested in order to make use of emissions data created by Pacific and Yukon Region and Prairie and Northern Region in MSC models such as AURAMS and CHRONOS. This latter project was helpful in facilitating a collaboration with Natural Resources Canada. Two tentative plans for future regional measurement/model inter-comparison studies were drawn up in the 2003/04 fiscal year in collaboration with Ontario Region and Prairie and Northern Region.
- Work with McGill University was carried out to use a mesoscale model with chemical processing to simulate two sample cases involving clouds for the purpose of helping Environment Canada scientists develop flight plans for the ICARTT study to be conducted during the summer of 2004. The simulated concentration fields will help determine the best locations to deploy the aircraft in order to observe chemical processing of pollutants by clouds.
- AQRB in collaboration with McGill University and the University of Montreal received funding from the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) to study the transformation of mercury in the Arctic through laboratory, field and modelling studies. During the 2003/04 fiscal year, springtime temporal dynamics of total and gaseous mercury in snowpacks from the high Arctic were investigated. Through *in situ* incubation experiments of snow samples, study findings showed that the production of volatile mercury in snow was photo-mediated and occurred in the first 3 cm of snow. Reactions of halogens and halogen oxides with mercury were also studied. The study revealed that bromine (Br) and bromine oxide (BrO) reactions are the most important reactions responsible for springtime mercury depletion events (MDEs) in the Arctic.
- Research with the Department of Geography at the University of Toronto was carried out to study and evaluate the fate distribution and fate of POPs in urban environments. This study was funded by the National Science and Engineering Research Council (NSERC). Through this collaboration one graduate student and one postdoctoral research fellow conducted research in the AQRB Thomson Labs. This study targeted the surface-air exchange and fate of POPs in organic films that coat impervious surfaces (e.g. concrete, asphalt, glass, roof shingles) that are typical in urban areas. The study will help parameterize a multimedia model of chemical fate in the urban environment. The results will further help in increasing the understanding of the role of urban areas as emission sources of POPs and risks posed to human populations residing in urban areas.
- A study with the Department of Chemistry at the University of Toronto was funded through CFCAS to investigate the role of forests in removing POPs from the atmosphere. A postdoctoral research fellow and PhD student used the AQRB's Micrometeorological Flux Tower at the Canadian Forces Base – CFB Borden to conduct intensive field sampling. The Thomson Lab was used to analyze the samples.
- The AQRB collaborated with Trent University to investigate the spatial and temporal distribution and surface-air exchange of persistent organic pollutants in the Great Lakes basin using a network of passive air samplers. Chemicals

investigated included legacy POPs such as PCBs and organochlorine pesticides as well as 'emerging' chemicals such as brominated flame retardants.

- The AQRB received CFCAS funding to do collaborative work with the University of Sherbrooke on aerosol remote sensing using passive and active radiometry. The work will involve several field studies at the Branch's Centre for Atmospheric Research Experiments (CARE) using both the scanning lidar (RASCAL) and zenith-pointing lidar (ALIAS) facilities to better understand the aerosol-optical-depth (AOD) and sky-scan profiles of the CIMEL sunphotometer. A co-supervised post-doctoral fellow and visiting scientist were involved in a 4-week long experiment in June 2003 at CARE using ALIAS, RASCAL and several sunphotometers. During this study a large smoke plume, between 4-9 km in altitude, covering the eastern half of North America was observed on June 2, 2003 (Figure 28).

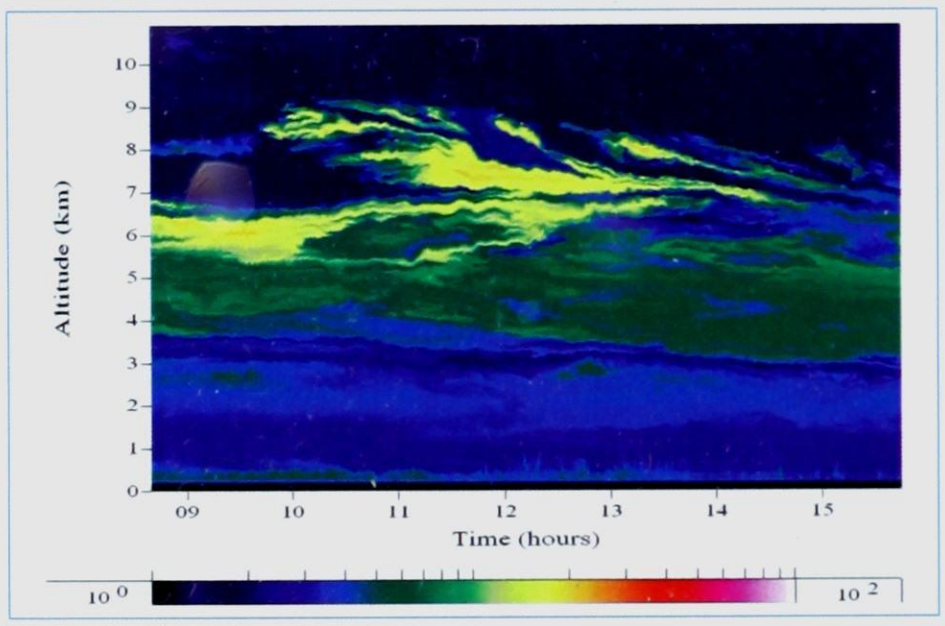


Figure 28 – Smoke plume (between 4-9 km) covering eastern North America on June 2, 2003

- The AQRB in collaboration with McGill University received a grant from NSERC to investigate the environmental impacts of natural and anthropogenic gases using remote sensing. Plans are underway to work with Resonance (in Barrie, ON) to develop a DOAS (Differential Optical Absorption Spectrometer) to measure various important chemical tracers in the atmosphere. A unique opportunity to apply new DOAS techniques with state-of-the-art scanning lidar technology will be of significant value to the scientific community.
- The Alert observatory continued to provide infrastructure for a number of global instrument programs led by other institutions (Australia's Commonwealth Scientific and Industrial Research Organisation – CSIRO in Australia, Scripps Institution of Oceanography-SIO and Climate Monitoring and Diagnostics Laboratory – CMDL in the United States, Universities of York in Canada and Heidelberg in Germany) as well as for greenhouse gas measurement inter-comparisons between MSC and agencies in other countries providing information to global databases.
- The infrastructure of the ASTRO observatory at Eureka, NWT, formerly part of the NDSC (Network for Detection of Stratospheric Change), has been made available to an academic consortium led by the University of Toronto, as part of CANDAC (Canadian Network for Detection of Atmospheric Change). Also, the NOAA component of the SEARCH program (Study of Environmental Arctic Change) is using both the Baseline Observatory at Alert, and facilities at Eureka, to initiate long-term measurements of radiation, cloud physics, aerosols and surface fluxes in the Arctic troposphere and planetary boundary layer.

Finance

The AQRB receives funding from three different Business Lines: Weather and Environmental Prediction which primarily supports the GHGs & Aerosols and Stratospheric Research Programs, Clean Environment (CE) which supports the Smog, HAPs and Acidic Deposition Research Programs, and Nature, which supports the Great Lakes component of the HAPs Research Program. Each business line is set up to deliver a specific long-term strategic outcome; therefore the research performed within AQRB contributes to achieving the following results:

1. through the Weather and Environmental Prediction business line, help Canadians adapt to their environment in ways that safeguard their health and safety, optimize economic activity and enhance environmental quality;
2. through the Clean Environment business line, help protect Canadians from domestic and global sources of pollution; and
3. through the Nature business line, help conserve biodiversity in healthy ecosystems.

Funding

Each business line contributes funding for salary, operating and maintenance expenses (O&M) and capital investments. AQRB's funding for the 2003/04 fiscal year is detailed below (in '000s):

Business Line	Salary	O&M	Capital	Total
WEP	$ 4,211.3	$ 2,983.9	$ 57.0	$ 7,252.2
CE	$ 2,515.0	$ 2,687.6	$ 143.0	$ 5,345.6
Nature	$ 205.0	$ 665.8		$ 870.8
Total	**$6,931.3**	**$6,337.3**	**$200.0**	**$13,468.6**

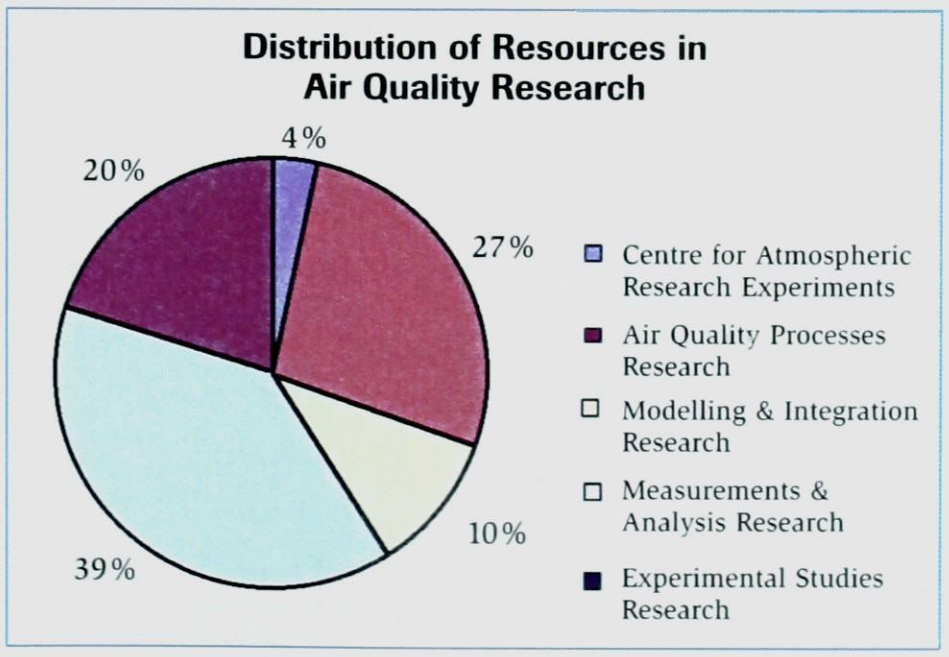
The budget that AQRB receives from Environment Canada's business lines is considered A-Base funding. This budget is augmented with funds from other sources, by amounts that vary from year to year. Significant sources of external funding include the Program for Energy Research and Development (PERD), the Great Lakes Water Quality Agreement and the Border Air Quality Strategy (BAQS). Other sources can include funding from other government departments and organizations (e.g. Health Canada, NRCAN, NOAA, CSA etc).

The Branch's budget for the fiscal year 2003/04 also includes Ozone Annex funding that began as a short-term initiative in 2001-02. In 2004/05 Ozone Annex funding will become a permanent source of funding and will be considered part of A-base funding.

The Strategic Capital allocation is determined each year on the basis of submissions to the Executive Committee of MSC. The strategic capital provided $263K in the 2003/04 fiscal year to help restore and replace branch equipment.

Expenditures

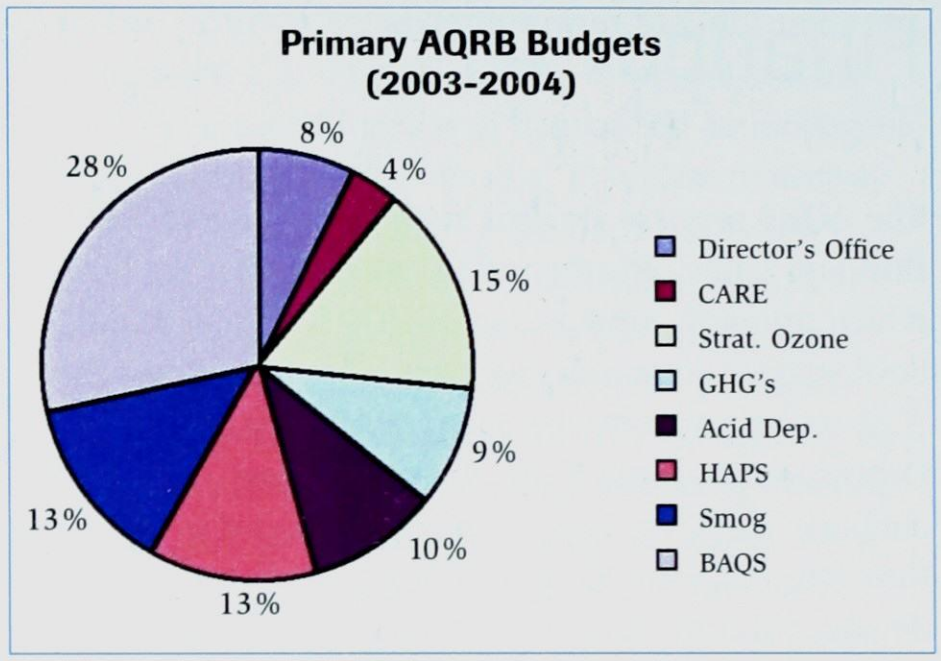
The AQRB's organizational structure parallels the four main functions it performs: Experimental Studies (ARQX), Measurements and Analysis Research (ARQM), Modelling and Integration Research (ARQI), and Processes Research (ARQP).



Funding is also provided to the Centre for Atmospheric Research Experiments (CARE) and to the Director's Office for items that benefit the Branch as a whole, for example, the Thomson Laboratory, computer maintenance, and conference travel.

AQRB is committed to the following main air quality issues:

- smog;
- acidic deposition;
- hazardous air pollutants (HAPs);
- greenhouse gases and aerosols (GHGs); and
- stratospheric ozone and radiation.



Human Resources

The AQRB (with a staff of over 150 employees) is dedicated and committed to ensuring that air quality science research remains excellent, credible and relevant. The Branch encourages training courses for staff and offers to their staff career development opportunities. Training and development is important to AQRB, especially in keeping up-to-date with the latest air quality issues affecting the country. In addition, AQRB staff members attend local, provincial, national and international conferences and training courses focused on a variety of air quality issues.

Training & Development

The Branch has taken stock of the supply of, and career opportunities for people with appropriate knowledge and expertise to help facilitate the understanding and interpretation of scientific information by stakeholders.

The Branch continues to promote workforce development by offering management opportunities to staff. Several scientists at the operational level were given an opportunity to take on managerial duties. As a manager, the scientist becomes more aware of how scientific research fits into the bigger picture and how the research feeds the information needs of the public and the scientific, policy and planning communities.

The Division Chiefs in the Branch were given corporate files to manage to broaden their management expertise and to further develop managerial competencies. Several staff were also given the opportunity to learn about and manage different divisions within the branch.

The Branch developed a training and development plan to monitor training and development activities and to ensure everyone in the Branch received the proper training and the necessary tools to do their work.

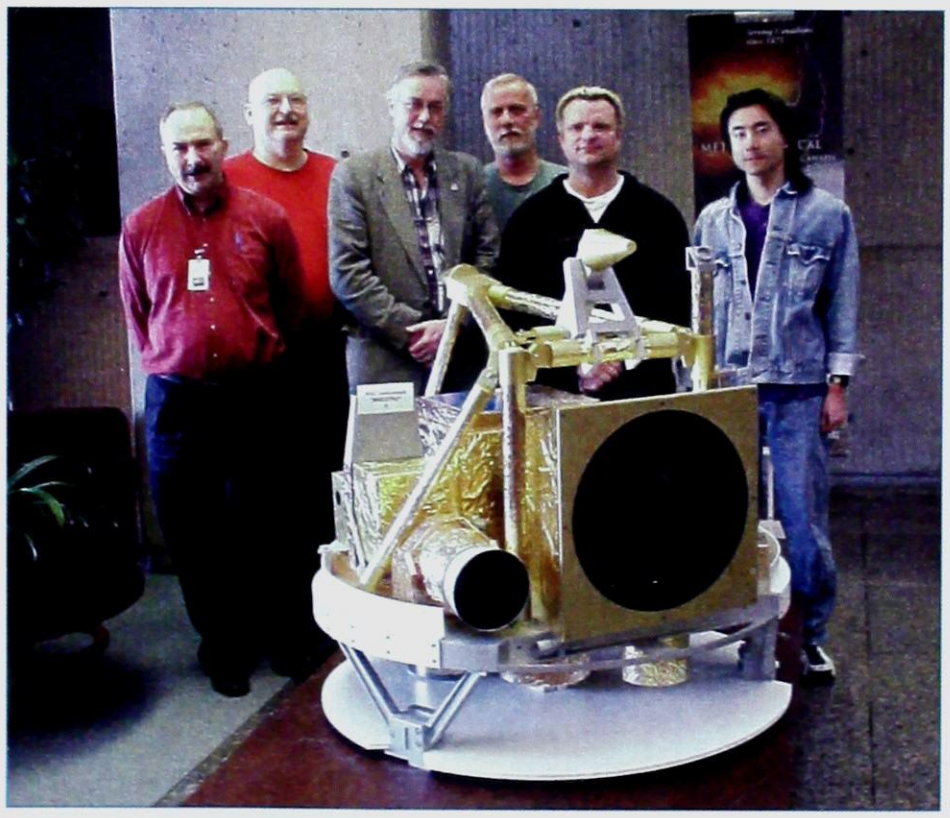
As part of career development, staff are encouraged to complete a personal development plan to identify their learning needs and career goals.

Health & Safety of Employees

The AQRB continues to have ongoing Health and Safety Committee meetings. The Committee informs decisions on safe practices for employees, especially those working out in the field and in the lab. The Committee also participates in Occupational Safety and Health (OSH) activities outside the branch and monitors the health and safety directives of the Department to enhance its health and safety initiatives.

Awards & Recognition

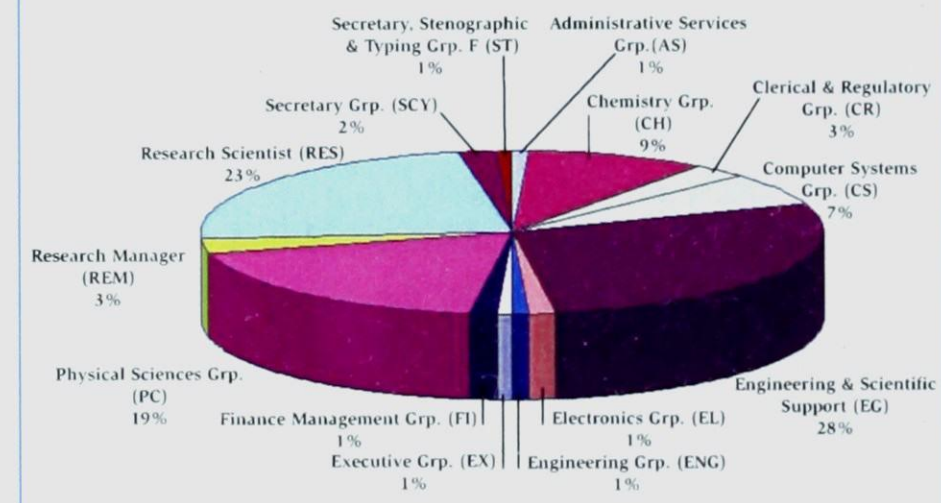
- **Canadian Space Agency: Certificate of Appreciation**
  In recognition of contributions made to the SCISAT-1 development by the MSC (see Stratospheric Ozone Research section), nine MSC-AQRB employees were awarded certificates of appreciation by the Canadian Space Agency (CSA). These certificates were presented to Dr. C. T. McElroy (Principal Investigator for MAESTRO), Dr. David Wardle, Clive Midwinter (now retired), David Barton, Robert Hall, Akira Ogyu, Aaron Ullberg, Dr. Yves Rochon and Dr. Chris McLinden.



(Left to right) Robert Hall, Aaron Ullberg, Tom McElroy, Clive Midwinter, David Barton and Akira Ogyu. Absent: David Wardle, Yves Rochon, Chris McLinden.

- **F. Weston Environmental Chemistry Award**
  Tom Harner, a young Research Scientist was awarded the Roy F. Weston Environmental Chemistry Award by the Society of Environmental Toxicology and Chemistry. This annual award is given to a scientist under the age of 40 for significant contributions to the environmental science field.
- **RES Promotions**
  Six research scientists were promoted by the Departmental RES Promotion Committee as a result of their leadership and competencies in the research area.

AQRB Workforce Distribution by Classification



Employment Equity

An AQRB staff member was recognized as the official employment equity champion for the Branch. Staff concerns/issues on diversity are directed to the champion who brings these issues to the senior management table. The champion is responsible for representing the voice of visible minorities and staff with disabilities.

2003/04 AQRB Journal Publications

2004

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