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AIR POLLUTION ACTIVITIES

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Air Quality and Inter-Environmental Research Branch

Introduction

The Air Quality and Inter-Environmental Research Branch consists of four Divisions as shown in Figure 1. In November 1976 the Branch had a permanent staff of 68 plus a number of NRC Post-Doctorate Fellows and temporary staff assigned to specific projects.

Some internal reorganization took place in 1976 as responsibilities for air quality monitoring and surveys were assigned to the Air Chemistry Criteria and Standards Division and the Atmospheric Dispersion Division. Also an air quality modelling group was formed within the Boundary Layer Research Division.

Many of the Branch's research projects are carried out in cooperation with other federal and provincial agencies and universities. In general the activities across the Branch dealt with measurement techniques, studies of atmospheric processes, the development of models, and environmental impacts including pollutant effects. Some major projects of this nature were the Long Range Transport of Air Pollutants, the Alberta Oil Sands Environmental Research Program and the Spruce Budworm Study in New Brunswick.

Besides the Science Subvention program the Branch administered 17 contracts for scientific research having a total value of \$288,372. These contracts are listed in Section 8.

A list of publications and reports by Branch staff for this period is provided at the end of the report.

The research activities related to air quality will be discussed under the following headings: Environmental Monitoring; Environmental Processes; Environmental Modelling and Impact Assessment; Environmental Techniques Development and Technology and Information Transfer. Following these activities a discussion of the major Branch projects will be described briefly.

1. Environmental Monitoring

Ten stations continue to be operated at rural and remote locations across Canada as part of the global air quality monitoring network of the World Meteorological Organization. The objective is to develop long-term records on background atmospheric composition. Special emphasis is placed on those constituents which may influence climate. All stations measure atmospheric turbidity and collect precipitation samples for subsequent chemical analysis.

This precipitation network has been strengthened with the acquisition of new precipitation collectors and the adoption of new sample shipping procedures. Chemical analyses are now contracted out to the CCIW laboratory, and should provide accurate data when quality assurance programs are instituted.

During 1975, Alert, N.W.T., and Sable Island were extensively tested for suitability as CO₂ sampling sites. Flask samples are now being obtained at both stations and analysed for CO₂ concentration by the Ocean Chemistry Division of DFE in Victoria, B.C. Arrangements were made with the Geophysical Monitoring for Climatic Change group in NOAA to obtain nuclei counts from one of the Ocean Station Papa weather ships during 1976.

The Branch has a continuing responsibility to act as lead agency in the Tall Tower Network. This cooperative network involving various levels of government as well as universities and private agencies, consists of some twenty towers across Canada, measuring wind speed, wind direction and temperature at various levels, and at maximum heights ranging from 60 to 300 meters. Data from all towers are collected, checked and archived in the Branch and are published quarterly in the "Meteorological Tower Bulletin" thus making data and analyses available to subscribers and other users, public and private, on a regular basis.

A project has been undertaken jointly with the University of Toronto and National Research Council to instrument the CN Tower in Toronto to provide data for research in structural design. The four levels of wind speed and direction (maximum level 555 meters) and three of temperature (maximum level 415 meters) will also add to our knowledge of vertical variation in atmospheric structure. The Division also plans to install instrumentation to measure ozone, oxides of nitrogen, particulates and sulfur dioxide up to three levels, to delineate the vertical distribution of oxidants and other precursors of photochemical smog, in conjunction with a current study of horizontal variation in the Toronto area.

2. Environmental Processes

a) Sudbury Dispersion Studies

The fifth in a series of tall stack dispersion studies, carried out jointly with the Ontario Environment Ministry, took place at Sudbury during two weeks in September. In addition to providing meteorological support to various projects of the Province and the Air Chemistry, Criteria and Standards Division, Dispersion Division staff undertook two separate investigations designed to relate the physical characteristics of the plume from the 380 meter smelter stack to the corresponding atmospheric structure. In the first, time-lapse photographic observations of plume-rise and plume vertical dimensions were taken for comparison with simultaneous minisonde profiles of temperature and wind structure. A good data set was obtained here for the light-wind, stable

case. For the second project, multiple correlation spectrometers (up to three) were used simultaneously at different distances downwind under the plume in order to study both the optimum methodology for SO₂ mass flux determinations and the variation of the horizontal dispersion coefficient with downwind distance. Attention was concentrated on periods of atmospheric stability and at the onset and during morning fumigations. Analysis of this Sudbury data is well underway.

b) Oxidation of SO₂

The oxidation of SO₂ to sulfuric acid and sulfates was studied at Sudbury using an instrumented helicopter during September of this year. Results from two different sampling methods were used to validate the measured oxidation rates. Samples of particulate matter were also collected to measure the sulfuric acid and metal content of the INCO smelter plume at varying downwind distances.

In the laboratory, a method is being developed to measure the ability of atmospheric aerosols to oxidize sulfur dioxide to sulfates. A special apparatus permits the exposure of aerosols to SO₂ at various concentrations and temperatures for selected time periods with subsequent analysis of the aerosol for sulfur uptake. Oxidation rates expected in the atmosphere will be derived from the experimental results and these will be applied to aerosols in polluted and "background" air as well as those in stack plumes.

c) Trans-boundary Trajectory Analyses

In cooperation with the Ontario Environment Ministry, the generation, build-up and dissipation of ozone levels across Southern Ontario are being investigated in relation to associated meteorological conditions. In particular, trajectory analyses are being applied to investigate the contributing effects of trans-boundary flows of photochemical precursors, large urban centers and lake-induced local circulations.

d) Toronto Oxidant Study

In the Toronto area a study of oxidants and their precursors was carried out in the summer of this year. Two sampling sites, Toronto Island and Maple were operated. Continuous air monitoring for NO_x, O₃, SO₂ was made during the summer months from June through October. In addition to particulate light scattering, particulate matter was collected on a daily basis for future analysis of sulfate content. The data will be studied to elucidate daily variations with respect to differing air masses in the Toronto area.

e) Boundary Layer Structure and Turbulence

Detailed knowledge of the boundary layer structure and turbulence is required for many applications such as pollutant dispersion, effects on aircraft and in the development of numerical models of the boundary layer. Towards this objective, several experimental studies of the boundary layer have been conducted over the past few years and the analyses of these data are continuing. One study has been to look at the budget of turbulent kinetic energy near the surface. The importance and complexity of the velocity-pressure gradient interactions have been shown. Another study has been an investigation of the turbulent velocity and temperature statistics in the layer from 30m to 300m above Lake Ontario. It was demonstrated that relatively simple scaling parameters could be used to bring order to the data. A third study is to investigate the effects

of inhomogeneous terrain on the wind and temperature profiles and hence on the mixing. To this end a measurement program was conducted in and adjacent to a crop canopy. The analysis is now underway.

f) GATE

The processing and analysis of GATE data has continued through 1976. By the end of the year the processing of all Canadian GATE data will be essentially finished. The scientific analyses have been concentrated on the radiation data and the boundary layer tethered balloon data. The results to date have shown the data to be of good quality and have revealed some interesting and as yet unexplained features. During the coming year an attempt will be made to couple the different data sets together in order to obtain a more comprehensive picture.

g) Polar Boundary Layer

During the winters of 1974 and 1975 a small programme was conducted to investigate the energy fluxes over a frozen lake surface. With the development internationally of the GARP Polar Sub-Programme and increasing Canadian interest in Arctic regions, it has been decided to proceed with a major long-term programme with the following objectives:

"To reach an understanding of the dynamic and thermodynamic processes in the Arctic Planetary Boundary Layer and the interaction of this layer with the underlying surface".

and

"To provide advice and consultation related to the impact of this layer on Arctic environmental problems including the prediction of weather and pollutant dispersion".

The first step in the programme will be a comprehensive boundary layer experiment over the ice of Lake Simcoe in February/March, 1977. This experiment will be a test of equipment and logistics as well as providing valuable data on the boundary layer over snow and ice surfaces. The acoustic sounder, tethered balloon and surface flux and profile measurement systems will be utilized in the experiment and it is expected that there will be concurrent flights by National Aeronautical Establishment aircraft.

Over the next few years the emphasis for this programme will be in the further analysis of existing data sets and the utilization of the measurement capability as part of or in support of the urban and polar boundary layer studies and Branch projects such as AOSERP, Spruce Budworm and others. The results from these other studies will frequently also be useful towards improving our general study of boundary layer structure and turbulence.

3. Environmental Modelling and Impact Assessment

a) Modelling

Since the bringing together of a group of scientists to specialize on modelling the urban environment a considerable amount of progress has been made. Within this activity area four programmes are underway. These are:

1. Development of a 3-D urban-mesoscale model
2. Process and slab modelling
3. Plume modelling
4. Modelling of flow over varying topography

For the urban-mesoscale model an existing model was borrowed and substantial modifications and improvements have been made. The running time of the model has been reduced by reprogramming the computations to make more optimum use of the computer. Experiments have been conducted on the effects of topography, boundary conditions and numerical integration schemes. This model will soon be available for experimental air quality potential studies.

Results from numerical models for studying the radiative effects of aerosols on thermal structure and pollutant dispersal have been presented at scientific meetings and are being prepared for publication. A slab model approach has been utilized to predict the growth of internal boundary layers. These studies will provide an alternate description of the urban boundary layer to facilitate the examination of several important problem areas. The work on plume modelling has been continued with the long term objective of being able to superimpose point plume sources on the 3-D urban-mesoscale grid point model. The work on the latter category, i.e., modelling of flow over varying topography, was carried out primarily by contract. Some useful results were obtained that will aid in the formulation of a more generalized 3-D model.

Most of the effort on the urban boundary layer problems has been in the modelling group. However, it is necessary that data be obtained for purposes of initialization, verification and for further understanding of the physical and chemical processes. A Branch observational program of the urban boundary layer has been proposed for the future.

The Branch is involved in two hydrometeorological modelling projects. The purpose of the Large-Scale Water-Balance Project is to produce national maps which provide improved estimates of mean precipitation, evapotranspiration and runoff. The analysis is based on a grid square system approach. The centres of the grids lie along latitude lines 1 degree apart and are spaced in the east-west direction so that each grid has an area of 10,000 km². The data that have been determined for each of the grid squares include mean annual observed precipitation (P) and runoff (N). When the (P) and (N) fields were combined with an estimate of the mean annual evapotranspiration field (E), assuming initially no error in (N), it appeared that mean annual precipitation was underestimated on the average by approximately 20 percent. This error is considered to be due to a combination of gauge deficiencies and inadequacies in the precipitation network. Studies are continuing to resolve the discrepancies in the water balance components.

The WMO Saint John Basin WWW Project examines the present and potential applications of the World Weather Watch to operational hydrology. A computer program for determining daily areal precipitation by sub-basin has been developed for use with the SSARR stream-flow forecast model. The program uses a "grid-square" technique to determine the daily areal precipitation. Comparisons will be made with the standard Thiessen polygon technique and stations will be selectively dropped from the analysis to maximize precipitation information from a minimum network of stations. A progress report on the multi-agency international project was prepared for the meeting of the WMO Commission for Hydrology in Ottawa in July. Representatives of AES Headquarters, Downsview, AES Atlantic Region, Halifax and the Canadian Meteorological Centre, Montreal met in November and arrangements were made for augmenting CMC precipitation and temperature forecasts for the Saint John Basin during the next snowmelt season.

In order to provide Regional staff with an expanded capability in air quality impact studies, interactive computer programs have been developed for Gaussian plume models under unlimited mixing, limited mixing and fumigation conditions. Documentation on these programs in the form of user's guide must now be prepared. It is proposed to expand these programs in the future to include modifications to plume-rise formulations, alternate dispersion coefficient relationships and to take into account such things as terrain and non-homogeneous atmospheric structure.

A study has been completed which examined the applicability of the Pasquill-Gifford stability classification scheme for Canadian conditions. These synthetic classifications determined from surface meteorological observations were compared to classifications determined directly from measurements of vertical temperature gradient taken during several field studies at various locations. Direct agreement was only found in 22% of the cases and agreement to within one stability class occurred only 57% of the time. The departures, however, appear to have a significant enough systematic component that further work may permit the Pasquill-Gifford scheme to be usefully adjusted.

A multiple-cell trajectory model has been used to calculate the concentration of nitrogen oxides in Edmonton. Model predictions have been tested with data collected during field studies and satisfactory agreement has been obtained.

Mathematical models have been developed for treating dispersion and chemical transformations of reactive pollutants in chimney plumes. The models have been applied to predict oxidation of sulfur dioxide to sulfates in the plume of the INCO superstack at Sudbury, as well as nitric oxide to nitrogen dioxide in the Nanticoke generating station plume.

A model of SO₂ washout and redistribution in the atmosphere has been developed which utilizes a more accurate description of droplet-air exchange of SO₂ than has hitherto been used. Results of an application of the model to the pollutant plume will soon be completed.

chemistry network of stations
existing in the Atlantic were being
is to investigate regional differences
and wet deposition of pollutants
with this network AES is providing operations
to Inland Waters Directorate for the operation
precipitation samplers across the country which are
used to sample precipitation for the analysis of organic
constituents (i.e. organo-phosphates, PCB's, etc.)

In order to define medium-range pollutant transport in the boundary-layer, an air parcel trajectory model has been developed which derives representative winds from observed fields of surface pressure, an objective analysis technique for hourly data in a 31 x 28 grid system with a grid length of 127km, and appropriate corrections for surface frictional effects. For final trajectories (back or forward time step), hourly wind vectors are integrated over periods up to 2-3 days. This model is currently being applied in studies of the source regions for photochemical ozone and for sulfate aerosol measured at Canadian monitoring sites.

For application to the long-range transport of pollutants, an operating three-dimensional trajectory model has been developed which can be used in the determination of the pollutant concentration fields using an emissions inventory for input. The model uses the objectively analysed height, temperature and wind fields from the Canadian Meteorological Center history data base to compute backward or forward trajectory segments in three dimensions at user-specified levels below 5km. and for specified time intervals and durations (currently 3 hour steps for up to 5 days). The model can operate anywhere in the Northern Hemisphere using data currently archived at the Canadian Meteorological Center.

Finally, reviews were carried out for two large air quality impact study reports prepared by consultants for Syncrude, Alberta, and for the proposed Afton Mine/Mill/Smelter, B.C.

b) Impact Assessment

The earth's surface receives materials from the atmosphere in gaseous and particulate form and in precipitation. Increasing attention is being directed to assessing the relative importance of these deposition processes under various combinations of atmospheric concentrations, surface characteristics and meteorological conditions. Deposition in precipitation appears to be the most important single contributor and field work was largely confined to precipitation chemistry.

The Branch carried out work on two major programs in support of the Long Range Transport of Air Pollution (LRTAP):

- i) An intensive study of sulfates during August, 1976. This was a joint AES-EPS program using a relatively dense network of Hi-Volume samplers located in rural environments to gain some insight into the distribution of sulfates over eastern Canada. In conjunction with this program, the daily rain samples for chemical analysis were collected.
- ii) The Canadian Network for Sampling Precipitation (CANSAP). Work was begun on the establishment of a new precipitation chemistry network of fifty stations across Canada. The existing 10 WMO stations were incorporated. Its objective is to investigate regional differences in the concentration and wet deposition of major ions in Canada. In conjunction with this network AES is providing operational assistance to Inland Waters Directorate for the operation of twelve precipitation samplers across the country which are being used to sample precipitation for the analysis of organic constituents (ie. organo-phosphates, PCB's, etc.).

Research on plant injury by air pollution continued in 1976 toward the objective of developing quantitative relationships between plant injury and pollutant uptake, as determined by plant physiological responses and environmental conditions. As in past years, research was conducted jointly by the Hydrometeorology and Environmental Impact Research Division and the University of Guelph under contract. In-canopy studies have been the responsibility of the University of Guelph, while the Division's studies concentrated on determining total pollutant fluxes from above-canopy measurements. The problem investigated was ozone and "flecking" of tobacco. The choice of tobacco was not predicated upon particular interest in economic loss to this crop, but upon several other factors. The Biometeorology Section has had previous experience with the problem of ozone injury of tobacco; the tobacco-growing area of Ontario near Lake Erie suffers from a high-incidence of ozone fumigations resulting in regular damage to the crop; tobacco "flecking" provides an easily-recognizable indication of injury and injury rating schemes are available; and in-canopy measurements are facilitated by the tall tobacco canopy. It is intended to extend results or techniques derived to other crops in the future. A literature survey on the subject of nitrous oxide fluxes by fertilizers has been carried out to investigate the possible harmful effects to the atmosphere of the widespread use of agricultural fertilizers. A paper was presented at a symposium on the status of research into the N₂ cycle organized by the Institute for Environmental Studies of the University of Toronto.

An assessment of the impact of air pollution on vegetation has continued around St. John, New Brunswick. This study has two objectives:

- a) To construct an index of atmospheric purity based on plant species frequency, cover values and distribution. This index will describe the already existing response of the vegetation types to changes in air quality.
- b) To monitor the input of some pollutants, e.g. heavy metals, into the ecosystem by the analysis of permanent vegetation plots.

The analysis of vegetation from remote areas e.g., High Arctic, is currently in progress to obtain background values for various pollutants. Such large scale geographical surveys have been extensively carried out in Scandinavia and thus allow for comparisons to be made of the existing metal and sulfur burdens. Such comparisons could provide a baseline for the study of the long-range transport of atmospheric pollutants.

A third project is concerned with potential effects of changes in air quality on Arctic vegetation and, in particular, lichens which are of a vital importance in this ecosystem. The project is being carried out in two phases:

- a) A laboratory-oriented study of the effect of different pollutants e.g. SO₂, on the physiology of lichens in order to define the critical concentrations which produce metabolic damage. In addition, the effects of the changing micro-climate e.g., light, temperature and humidity, on the sensitivity of these plants to air pollution is being assessed.
- b) A field study in which lichen communities in the Arctic are being monitored continually in order to describe the energy budget and microclimatology characteristics of the different vegetation types.

As part of the AOSERP programme a study has been initiated whereby epiphytic lichens are being analysed for their heavy metal and sulfur content in order to define atmospheric deposition patterns around the local sources. This study in collaboration with precipitation and aerosol measurements will allow for a rationalisation of the observed changes in the vegetation of the area.

Criteria for the effects of mixture of air pollutants on horticultural crops are being developed under contract to the University of Guelph.

A workshop on Canadian research on development of Criteria and Standards for Air Pollutants is in the planning stage.

4. Environmental Techniques Development

Several projects involving new instrument development have been completed this year. One of these was the development of the SPED (Speed Proportional Elapsed Distance) counter which allows field data to be recorded on strip charts in a mode where the results are linear with the elapsed distance covered by the mobile research vehicle. The counter was used quite successfully in the September 1976 Sudbury, Ontario Field Study.

Kautsky Apparatus, which measures the fluorescence from chlorophyll in living plants, is nearing the end of construction. When this hand-held field unit is placed into contact with a leaf, the time decay of the fluorescent activity of the chlorophyll can be examined for the photosynthetic response of the plant. The device will be used to study air pollution damage in living plants.

A system, consisting of a gas chromatograph with an electron capture detector, has been developed for the automated measurement of freons, other light halocarbons and nitrous oxide. It will be used in field projects to investigate seasonal variations in ambient nitrous oxide concentrations and measure freons in an attempt to validate trajectory analyses.

A spectrophotometer with its associated optics has been assembled and diffuse solar irradiance measurements (300-500nm) have been made at Toronto Island and 4905 Dufferin Street, Downsview. Future absolute measurements under differing meteorological conditions will include the direct solar irradiance. These data are essential for proper modelling of photochemical air pollution.

A measurement technique for nitrous acid, an important precursor in photochemical smog formation, is currently being developed. It will be used in laboratory studies to investigate chain reactions important in the formation of ozone. The results will be applied to the development of special chemical models for the formation of oxidants in polluted urban atmospheres.

Air sampling devices, using special filtering techniques, have been developed to measure sulfate particulate matter and sulfur dioxide in the same air sample. Analysis of the filters by an isotope-dilution technique, has provided the sensitivity and accuracy necessary to measure background sulfur concentrations. This sampling method and analytical technique have been used in field studies at Sudbury during September to determine oxidation rates of sulfur dioxide in plumes. It is planned to use this technique during the Alberta Oil Sands Research Field Project in 1977.

A project nearing completion is the development of a polar nephelometer prototype. This device measures the amount of light scattered as a function of angle (thus the name polar) by aerosol particles. The information obtained can be used to categorize the number of aerosol particles per unit volume of air sampled as well as the size distribution of those aerosol particles.

In order to increase our capability to make measurements throughout the boundary layer, a simultaneous programme of measurement systems development has been going on. The tethered balloon system, developed for the GATE, has been refined and was used during the AOSERP and the Spruce Budworm Experiments. An acoustic sounder system is being developed jointly with the Atmospheric Instrument Branch and a prototype was operated in AOSERP and the Spruce Budworm Experiments. These systems when coupled with our improved surface layer measurement and data acquisition systems provide an excellent boundary layer measurement capability.

The Branch has, for the past number of years, carried on a program to determine the performance of various precipitation gauges for the measurement of snowfall and snow samplers for the measurement of snowpack. Favourable meteorological conditions during the winter of 1975-76 led to a successful field season. Snow gauge comparisons were obtained at the Cold Creek Research Station, at the Woodbridge Research Station and initial results at the Monticello climatological station. The ratio of gauge catch to ground truth, as measured on a snow board in a sheltered location, was analysed in relation to mean wind speed during the storm, crystal structure, surface and upper air temperatures. The gauges used in the study are M.S.C. Nipher shielded snow gauge, Fischer and Porter Recording Precipitation Gauge, Universal Recording Precipitation Gauge and the Tretykov Precipitation Gauge. Results indicate that the M.S.C. Nipher Shielded Snow Gauge gives superior performance. "Best fit" equations for relating the catch ratio to wind speed and surface temperature are currently in preparation. These experiments on gauge catch will continue during 1976-77 as part of the international study being carried out by the World Meteorological Organization Commission for Instruments and Methods of Observation (WMO/CIMO).

5. Technology and Information Transfer

During the reporting period over 100 publications and/or reports have been prepared. These articles cover in detail much of the work carried out by the Air Quality and Inter-Environmental Research Branch. A listing of these is appended.

The Canadian contribution to the WMO Snow Studies by Satellite Project was brought to a successful conclusion with the presentation of five reports at the International Seminar held in Geneva in October. The Canadian studies were coordinated through the Task Force on Snow and Ice (H.L. Ferguson, Chairman) of the CACRS Working Group on Hydrology. Reports were prepared by scientists from AES, Inland Waters Directorate of EMS, B.C. Hydro and the Canada Centre for Remote Sensing. A number of provincial agencies provided "ground truth" data for the projects. The Hydrometeorology and Environmental Impact Research Division reported the results of studies on the Saint John and Souris Basins. Basic imagery used in the analysis was NOAA/VHRR imagery received by the AES Satellite Data Laboratory in Downsview, enhanced to facilitate snow cover analysis. This was supplemented by LANDSAT I and II data for the period February to April, 1976. Snow cover analyses using conventional surface data only were compared to analyses based on both surface and satellite data.

Part of the Branch's objectives is to have the capability for the extension and application of meteorological knowledge for the evaluation of evapotranspiration and evaporation. Studies of these processes are being conducted at the Woodbridge Research Station. Part of the emphasis has been placed on determining evaporation from snowpacks. To this end, a contract to study the energy balance of areas partly covered by snow was let to the University of Toronto.

Field studies were continued and a number of reports were written in support of the Working Group on Precipitation, Evaporation and Soil Moisture of the WMO (CIMO). Measurements of snow from a lysimeter were compared with measurements from a number of gauges. Studies of evaporation from various types of pans continued. A report on soil moisture measurements was prepared. This report reviewed 35 papers and listed over 60 references. In November the Working Group on Hydrology of the Canadian Advisory Committee on Remote Sensing (CACRS) and the Canadian Remote Sensing Society sponsored a Workshop on Soil Moisture and Groundwater. A paper entitled "Methods of Assessment of Ground Truth Soil Moisture", was presented at this Workshop. It was based on a review of the literature and work conducted for the WMO study on neutron meters, as well as on experiments on sensing of soil moisture by the natural gamma technique.

An air pollution potential climatology for Canada, in the form of an analysis of mean monthly, seasonal and annual values of maximum mixing height, wind speed and ventilation coefficient has been accepted for publication by "Atmosphere". Details on the joint frequency distributions of pollution potential parameters have been placed on microfiche for all Canadian upper air stations and the associated user's manual is being prepared.

A three-day seminar on the Environmental Assessment and Review Process (EARP) was organized by the Branch and held at AES Headquarters in April. This involved 10 Scientific Services meteorologists from all Regions, 16 Headquarters scientists and 3 guest speakers.

Science Subvention Program

During the 1976-77 period a number of research programs was carried out under the science subvention program as well as by direct research contracts. These activities fall into two broad categories, i.e., studies related to the physics and chemistry of the atmosphere, and studies related to the effects of meteorological conditions and air quality on water, soil and vegetation. The latter information is used in assessing the applicability of cause/effect criteria to Canadian conditions with subsequent promulgation of national air quality objectives.

Federal-Provincial

AES has one member on the Federal-Provincial Committee on Air Pollution, and AES scientists were members of several of its sub-committees: on National Air Quality Objectives, on Maximum Tolerable Levels; on Air Quality Indices; and on Air Monitoring Site Selection.

International

AES scientists continued to be active in various intergovernmental bodies and international scientific organizations working in areas such as IJC Air Pollution Advisory Board, the long-range transport of pollutants (OECD and ECE Working Groups), multiple-source modelling of urban pollution (NATO/CCMS pilot study on Assessment Methodology and Modelling and associated Working Groups), environmental monitoring and assessment (WMO and WHO Working Groups) (UNEP) (ICSU) atmospheric chemistry and global pollution (WMO) climatic change and the assessment of human activities as a change-forming mechanism (WMO Working Groups) (GARP; Global Atmospheric Research Program) and the input of airborne material to receptor surfaces (WMO Rapporteur on Plant Injury by Air Pollution).

The Branch provided special training through a familiarization programme in air pollution meteorology to Dr. A. Akrawi, Iraq, Mr. Aredshir Farhang, Iran and Mr. Guillermo Berri, Argentina. This training was provided in co-operation with WMO.

Assistance was given through WHO in the preparation of a Clean Air Act for the State of Sao Paulo, Brazil. Consultation on the interpretation of air pollution data and its relationship to meteorological conditions was also provided to the Cuban Government through the WMO Pan American Health Organization.

Such international contacts provided an exchange of information on a wide variety of actual or potential air pollution problems requiring a strong leadership role at the federal level of government.

6. Major Branch Projects

6.1 Long-Range Transport of Air Pollutants

In response to observations of the increasing extent of acid precipitation and of atmospheric haziness in eastern Canada, the AES convened a meeting of Departmental scientists to review existing evidence for the occurrence and effects of long-range air pollutant transport in Canada and to assess the adequacy of current research and monitoring programs. The report of this ad hoc group became the basis for a submission to DFE Management Committee in August, 1976, when it was decided that the Department should undertake, as a high priority item, the development of an integrated program on the long-range transport problem with AES as lead agency.

The objectives of the program are to determine the current or baseline state of the environment in Canada prior to the impact of emissions from projected increased coal-burning in the USA and Canada, and to develop a clear understanding of the occurrence and effects of long-range transport within and into Canada including geographical extent, severity and socio-economic costs. Initially, efforts will be concentrated on sulfur compounds and on eastern Canada.

In the meantime, AES has undertaken two programs to provide basic data to evaluate the situation. A network of 40 precipitation chemistry monitoring stations is being installed across Canada, with emphasis on the East, which will become fully operational in April, 1977. Further, during August, 1976, AES and EPS carried out a joint intensive study of daily concentrations of particulate and precipitation sulfate at 30 "clean" stations across eastern Canada. Results of this study are available.

It is anticipated that the AES portion of the DFE program on the long-range transport of air pollution will involve three components: the development of trajectory analysis and more advanced long-range transport modelling capabilities; the development of a network of stations to measure concentration and deposition of sulfate compounds; and supporting research on processes, techniques, etc. In addition, close contact will be maintained with related European (OECD, LRTAP, ECE, EMP) and U.S. (MAP3S, MISTT, NADN, STATE, SURE) programs in order to ensure comparability of techniques and data and to provide information exchange.

6.2 Alberta Oil Sands Environmental Research Program

The Branch has continued to contribute to AOSERP through participation in the meteorological data acquisition, applied research and air quality modelling activities of the latter's Meteorology and Air Quality Technical Research Committee.

Vigorous efforts have been directed toward the establishment of a meteorological data base for the Oil Sands area. Ten climatological stations are now providing output routinely and the 500' meteorological tower is fully instrumented and operating. Related data-handling procedures are currently being developed and tested. A mobile minisonde system, complete with automatic data analysis and plotting, has been set up but the program of routine temperature and wind sounding of the lower atmosphere has been delayed by slow delivery of the required sondes. A feasibility study on the application of balloon-tracking radar to the minisonde program has been carried out jointly with the Ministry of Transport with positive results. Finally, reports on the first intensive field study carried out in March, 1976, have been completed and related seminars were presented in Edmonton and in Toronto. A second intensive field study in February, 1977 was carried out. Measurements included in-plume SO₂ oxidation and background air chemistry. Studies of patterns of pollutant uptake by snow and by lichens were set back due to unfavourable snow conditions.

Research projects on the air pollution potential climatology and the climatology of low-level air trajectories were completed for the Oil Sands area. New and ongoing research, in addition to that mentioned above, involves potential transformation processes for Oil Sands air pollutants, pollutant deposition processes and the derivation of plume dispersion coefficients from tower-mounted bivariate measurements.

The impact of extensive Oil Sands development upon the air quality of the study area may, in principle, be estimated by using mathematical models to predict pollutant concentration distributions for relevant source properties and appropriate meteorological conditions. Current modelling activities are focussed on two projects. In the first, the simple Climatological Dispersion Model is being applied in an attempt to provide gross estimates of seasonal and annual average concentrations. Secondly, a critical literature survey is underway to determine which regional dispersion models should be applied, adapted or pursued further in the program.

6.3 Spruce Budworm Project

The Branch again played an active role in the field program of the New Brunswick Spruce Budworm Adult Dispersal Project, a multi-disciplinary study under the general direction and sponsorship of the Maritimes Forest Research Centre, C.F.S., Fredericton. The objective of the participation this year was to determine the origin of mesoscale convergence features which on several occasions in the past few seasons had been observed to produce line-concentrations of spruce budworm moths over central New Brunswick.

It consisted of two major components: a special mesoscale surface observing network established in southern New Brunswick to collect data through June until mid July, and an atmospheric sounding program for the lowest one to two kilometers in the same area operating during the active moth migration period. The upper air program involved AES minisonde units, the tethersonde, acoustic sounder and special radiosondes at CFB Gagetown.

Data abstraction and analysis are underway with part of the work being carried under contract. The most significant moth-concentration event observed during the 1976 field season was well-documented by meteorological observations and this particular feature can be traced back to the Bay of Fundy.

7. Stratospheric Pollution

Two high altitude research balloon flights of Project STRATOPROBE III were carried out on August 19 and August 28 from Yorkton, Saskatchewan. On the first flight at a lower altitude, simultaneous measurements of the nitrogen chemistry of the ozone layer were obtained. Measurements of the nitrogen constituents on the three years have proven to be very reproducible and similar to the original measurements from 1974. The STRATOPROBE measurements demonstrate that the ozone layer is stable at Canadian latitudes in late summer and this is a good location for studies of stratospheric photochemistry.

The measurements of nitrogen photochemistry from 1974, 1975 and 1976 are consistent with current schemes employed in the stratospheric pollution models. These odd nitrogen constituent measurements together with the accompanying N₂O measurements indicate that if N₂O levels in the troposphere were to be increased significantly due to projected fertilizer usage in agricultural activities, a serious depletion of the ozone shield would occur.

Successful measurements of the chlorine chemistry of the ozone layer including HF, HCl and ClO were obtained on the August 28 flight. These measurements of the amounts of the active chlorine compounds (ClO, HCl) released from source chlorine compounds (F11, F12, CCl₄, CH₃Cl, etc.) should provide a definitive test of model projections of ozone depletion by freons. These models predict increases of UV radiation in the range of 10 to 40% at current freon release rates.

A Canadian report (Atm. Sci. Bull. 4/76) on the problem of ozone depletion by freons was prepared by the AES Advisory Committee on Stratospheric Pollution.

ARQO Contracts 1976/77

This report recommended the phasing out of non-essential uses of freons which would reduce freon release rates by 50% and gain an additional 15 years to evaluate the problem more precisely.

AES continues to operate the Canadian ozone network and in conjunction with Canadian industry has developed a new ozone monitoring instrument. These contributions to the world ozone monitoring network should improve the capability to detect downward trends in global ozone caused by man's activities.

A list of reports and publications from the stratospheric pollution studies is attached.

Dr. P. ...
Univ. of Toronto

Mr. B. ...
Univ. of Toronto

Optech, Inc.

Aeros Consulting
Services Ltd.

Dr. K.M. ...
Univ. of Guelph

Dr. F.K. ...
Univ. of Toronto

Dr. G. ...
Univ. of Toronto

Dr. D.M. Gray
Univ. of Saskatchewan

Department of ...
Government of Canada

Atmospheric ...
Research Station

Atmospheric ...
Sud Lake INP, Sask.

3. ARQD Contracts 1976/77

Contractor	Title or Purpose	Amount
Mr. H. Hinde Univ. of New Brunswick	Index of Atmospheric Pollution for the St. John Region	\$ 6,240.
Dr. T. Gillespie Mr. B. Grace Univ. of Guelph	Study of the potential air pollution damage to primary producers in Arctic and Subarctic environments	26,660.
Dr. M.S.A. Ahmed	Abstraction of strip-chart records and processing and filing of data on computer tapes	2,240.
Dr. J.M. Gray	Field evaluation of a halo-carbon monitor	2,500.
Mr. M. Fattori	Analysis of vegetation samples to determine the background concentration of atmospheric contaminants	5,000.
Dr. E. Nieboer Laurentian Univ.	Biological Indices of Atmospheric Pollution	6,112.
Mr. R.G.V. Hancock Univ. of Toronto	Analysis of vegetation samples	540.
Optech, Inc.	Design and development of a laser radar	151,917.
Acres Consulting Services Ltd.	A climatology of low-level air trajectories in the Alberta Oil Sands Area	20,000.
Dr. K.M. King Univ. of Guelph	Field study of plant injury by air pollution in food crops	9,700.
Dr. F.K. Hare Univ. of Toronto	Study of the large-scale water balance of Canada	4,800
Dr. G. Sceicz Univ. of Toronto	Data collection and abstraction for the Cold Creek Research Basin	7,100.
Dr. D.M. Gray Univ. of Saskatchewan	Area variability of precipitation - Bad Lake IHP Basin	7,000.

(cont'd.) ARQD Contracts 1976/77

Contractor	Title or Purpose	Amount
Mr. D. Storr	Analysis of Marmot Creek IHP Basin data	\$ 4,800.
MEP Company	Analysis of Spruce Budworm Project data	18,000
Dr. K.M. King Univ. of Guelph	Soil Moisture CIMO Project	14,157
Dr. G. Sceicz Univ. of Toronto	Woodbridge Snowpack Energy Balance	1,606.

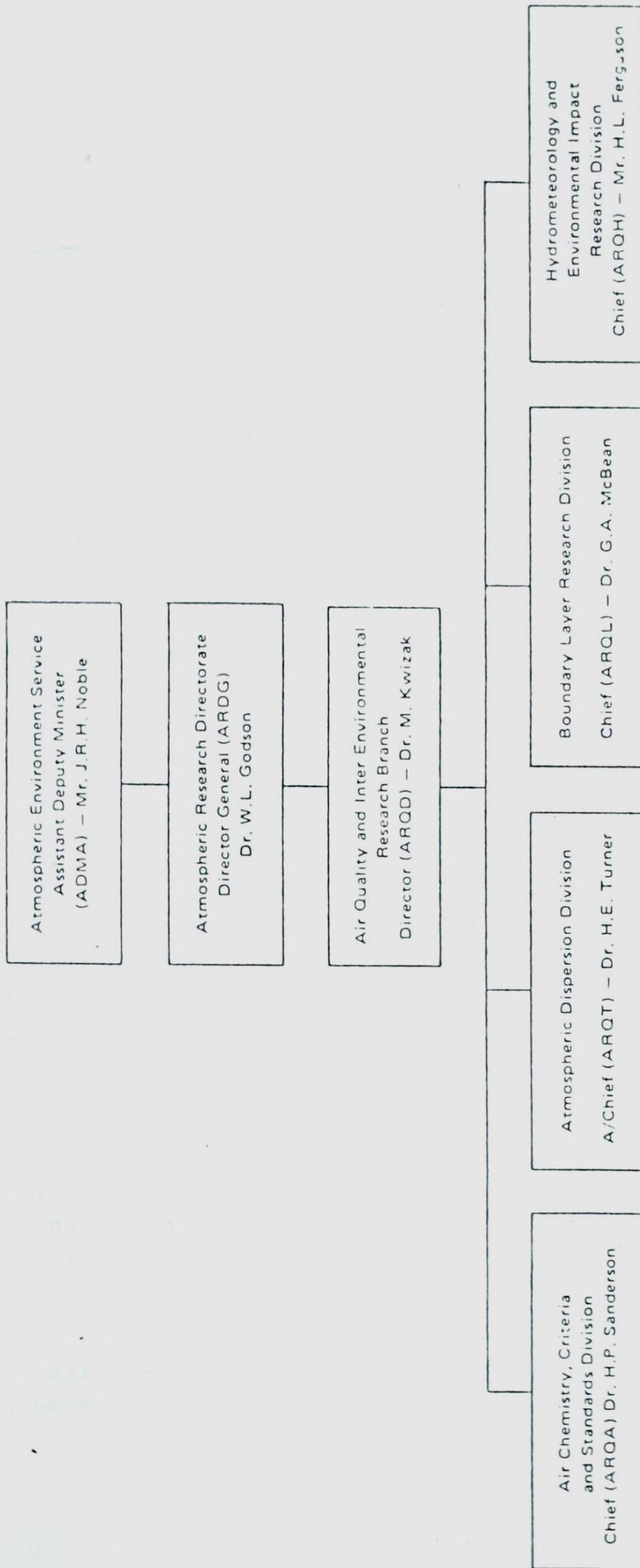


Figure 1 - Divisional organization and reporting relationships in the Air Quality and Inter-Environmental Research Branch, December, 1976

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