Environment Canada

Weather and Environmental Prediction

Research Agenda

2000 - 2005

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Contents

1.0 The Weather and Environmental Prediction Business Line

The Weather and Environmental Prediction (WEP) Business Line is part of a co-operative international program that monitors and predicts changes in the global atmosphere (weather, climate, atmospheric chemistry), hydrosphere (rivers, lakes, oceans) and the cryosphere (snow and ice). It contributes to scientific understanding of weather and climate systems, and atmospheric chemistry. It helps to define the inter-relationships that exist between changes in the physics and chemistry of the atmosphere and changes in weather, climate, air quality and hydrology and how they impact on human and natural ecosystems. In addition, WEP conducts research on strategies for adaptation to these atmospheric changes and their impacts, and conducts assessments of the state of atmospheric science in support of policy development.

The WEP Business Line provides:

- Health and safety warnings
- Weather and environmental information for effective and efficient decision making (e.g., health, economic efficiency, environmental quality, adaptation and reduced economic loss)
- Knowledge and understanding to implement environmental policies that are based on sound science

1.1 Environment Canada's Management Framework

BUSINESS LINE	CLEAN ENVIRONMENT	NATURE	WEATHER AND ENVIRONMENTAL PREDICTIONS	MANAGEMENT, ADMINISTRATION AND POLICY
OUTCOME	Protection from domestic and global sources of pollution	Conservation of biodiversity in healthy ecosystems	Adaptation to weather and related environmental influences and impacts on human health and safety, economic prosperity and environmental quality	Strategic and effective departmental management to achieve environmental results
RESULTS	*Adverse human impact on the atmosphere and on air quality is reduced* **The environmental and human health threats posed by toxic substances of concern are reduced* *****	**Biological diversity is conserved* ***** *****_Human impacts on the health of ecosystems are understood and reduced_ ***** *Priority ecosystems are conserved and restored*	*The impact of weather and related environmental hazards on health, safety and the economy is reduced* *Adaptation to day-to-day and long term changes in atmospheric, hydrological and ice conditions*	Strategic and integrated policy priorities and plans Efficient and innovative shared services

WEP research primarily contributes to the three 'RESULTS' (underlined and in italics) in the management framework table above, but it also provides scientific input for the 'RESULTS' in the table which are marked with an asterisk.

1.2 Links to Clean Environment and Nature Business Lines

The WEP Business Line supports the other business lines by providing the scientific basis for clean air and climate policy development by the ***Clean Environment*** Business Line. It provides relevant scientific information, scenarios and predictions (climate and air quality) to both the ***Nature*** Business Line and the ***Clean Environment*** Business Line for their scientific activities.

Clean Environment Business Line

The scientific information, model scenarios and science assessments produced by WEP provide the scientific basis for policy development by the Clean Environment Business Line. The air quality forecasts allow Canadians to take action to avoid the health impacts of smog, ozone, and particulate matter in the atmosphere.

Nature Business Line

The scientific information derived from WEP monitoring, process, and modelling research provides input to the Nature Business Line research related to biodiversity, human impacts on ecosystems, and ecosystem health.

2.0 WEP Research Framework

The WEP research agenda emphasises the importance of the atmospheric sciences in support of service delivery, policy development and building capacity for Canadians to adapt to a changing environment and to practice sustainable development.

The research generated under the WEP Business Line provides the scientific knowledge and understanding of the physics and chemistry of the atmosphere that is the scientific basis for Canada's weather forecasting and warning capabilities and the development of policies on climate change, clean air, ozone depletion and water resources.

WEP Research Agenda (2000-2005)

The strategic directions for this research include the following:

- Striving for a better understanding of physical and chemical processes of the atmosphere and the climate system by conducting observational, process and modelling studies (including those necessary to understand and predict risks to Canadians).

- Taking an integrated approach to atmospheric environmental issues by drawing together and building on relevant aspects of meteorology, atmospheric chemistry and climate research.

- Defining and supporting the evolution of the atmospheric and hydrological observing systems, including, *inter alia,* automation, remote sensing, and data assimilation.

- Developing and enhancing the environmental prediction capabilities of the Department to improve the accuracy of our weather and hydrological forecasts, and our climate change, air quality and UVB predictions.

- Striving to better understand the susceptibility of Canada's natural and socio-economic systems to atmospheric change and variability, and to enhance the value of the Department's related environmental predictions to Canadians.

- Interacting with and supporting ecosystem-based research as it relates to the atmosphere and the climate system.

- Providing a sound scientific basis for policy development within the Department.

- Participating actively in global atmospheric and climate research communities in order to access and leverage international research and scientific efforts relevant to Canada's needs.

2.1 The WEP Research Elements

The basic elements of WEP research are:

- **Meteorology and Hydrology**
- **Climate**
- **Atmospheric Chemistry**
- **Adaptations and Impacts**
- **Science Assessment**

Research activities include systematic observations, remote sensing, field and process studies, modelling, socio-economic integration, and assessments of the 'state of science'. There are important linkages between the WEP research elements. Ultimately, all the knowledge resulting from research in laboratories and from field and simulation experiments is incorporated into major numerical modelling systems (e.g., GEM, GCM, AURAMS). Scientists use the models to further test hypotheses by comparing the model outputs with the observed data, past or present. The goal is to integrate knowledge from research elements into environmental predictions or ecosystem simulations. In this way, scientists can identify gaps in knowledge, identify further research priorities, and provide sound scientific input to policy makers.

Science assessment and integration of environmental issues across disciplines is an ongoing function that is critical to ensuring that our environmental policy is based on sound science. A science assessment provides a critical review and synthesis of the state of knowledge on a particular issue. A formal science assessment integrates knowledge from different environmental disciplines, details the current uncertainties of the science and their implications for public policy and provides a means to monitor the effectiveness of policies that have been implemented. The breadth of activity may range from local through regional and national to international. For the public it describes the science behind the issue, and for the research community it provides feedback with respect to future environmental research needs.

WEP objectives are achieved by scientists from different disciplines working together, and consequently making the 'whole' greater than the 'sum of the parts'. Important synergies that exist among the basic WEP research elements are listed below.

- Meteorological drivers for the air quality and hydrological forecast models are derived from the numerical weather prediction (NWP) programs

- Numerical methods, parameterisations and processes of both climate and weather models share many similarities and common elements

- knowledge generated by climate and NWP atmospheric modellers to correctly represent the heating effects of gases, and the cooling and nucleation properties of particles, both of which are essential in the climate and weather forecasting of temperature and precipitation

- Scenarios of future climate, predictions of extreme weather events and smog episodes are used as the input for adaptation and impacts research

- Science assessments integrate the knowledge produced by meteorological and hydrological, climate, atmospheric chemistry and socio-economic impacts scientists, and the international scientific community to provide useful and accurate pictures of the 'state of the science' for pertinent issues

3.0 Meeting the Challenges

During the last six years, the WEP research program was severely hit by budget reductions, as were other components within the government. WEP research programs were severely curtailed, the work force was reduced by 25%, very little new hiring was authorised, and the infrastructure was not rejuvenated. The consequences of these measures are now being felt. The average age of scientists is 44, with the largest cohort (59%) in the age range 50-54. Several senior scientists have departed with some of them having accepted positions in other countries. The salary conditions are making it increasingly difficult to attract the most qualified young postdoctoral fellows, and to retain our most talented senior scientists.

The scientific infrastructure itself is ageing, and the monitoring networks in climate, weather and air quality are deteriorating. For example, we are at the point where the detection of climate change signals or the verification of clean air objectives in parts of the country is almost impossible. Moreover, for the first time in over twenty years, some of the performance measures of our weather forecasts have started to decline, both in absolute terms and relative to other countries.

Our determination to overcome these challenges has resulted in overworked scientists and science managers. However, it has also led to the realisation of the benefits of developing and maintaining collaborations. Despite budget cuts, WEP has been able to maintain research support to university atmospheric and climate science programs through science subventions, industrial research chairs, and the Climate Research Network, but at a reduced level. Canada has only been able to maintain a fragile critical mass in atmospheric science. A successful WEP research strategy, able to meet these challenges, must rest on the pillars of partnership.

A significant increase in the number of scientists will be required to tackle the complex environmental problems of the future. There is a need for substantial reinvestment in departmental laboratories, global circulation and numerical weather models, and field research stations (such as Alert, Eureka and Egbert as well as research aircraft). These research and modelling facilities are critical to our mission, and provide important infrastructure for university research. At the same time, we need to continue to nurture and benefit from scientific talent in universities, provincial departments, and other research institutes, private or public (e.g., through grants, contributions, collaborations etc.). One approach is to establish programs similar to the Climate Research Network in other scientific disciplines such as weather and atmospheric chemistry. Another approach is to create networks of “virtual” institutes around high priority themes. These approaches promote the effective use of leveraging from other funding sources like NSERC, National Centres of Excellence, the Canadian Foundation for Innovation, or the private sector. The aim is to increase the critical mass of scientists focused on a given set of high priority environmental problems.

As we evolve slowly towards fully integrated environmental prediction systems, teams formed from across the Directorates, Services and Regions will be needed to deliver successful programs that meet the needs of stakeholders. As an example, data assimilation will be pervasive across climate, air quality and weather. Similarly, the elucidation of many atmospheric processes requires expertise from more than a single division or branch, and many regional problems are most effectively studied in partnerships. Thus, attention will be given to creating multidisciplinary (e.g. Branch / Service / Region) project teams within the Department to tackle today's and tomorrow's complex environmental problems.

4.0 Emerging Priorities

The WEP research program must address two major, closely related challenges. The first challenge involves an increase (by at least a factor of 50) in the amount of data beamed down to earth from observing satellites. By the year 2003, more than 4 gigabytes (4,000,000,000 bytes) of data could potentially be transmitted to major national meteorological centres every day! There will also be a related increase in the diversity of observations, including the usual surface variables, atmospheric state variables, and atmospheric chemical constituents.

Traditional surface based observations are taken simultaneously all over the world to provide a 'snapshot' of the atmosphere. With the advent of space-borne systems, large amounts of data are now being transmitted continuously. These observations are unevenly distributed in four dimensions (three in space and one in time). The inclusion of the time dimension in analysis is referred to as four-dimensional data assimilation. It involves the blending of all available data in numerical forecast models to get the most accurate estimate of the initial state of the atmosphere. The blending requires advanced data assimilation techniques. WEP research on advanced assimilation methods began five years ago, but a significant increase in effort will be required particularly in areas dealing with the data assimilation of atmospheric chemical constituents.

The second challenge is related to the inexorable trend towards fully integrated environmental prediction models that combine multiple processes (biological, chemical, physical, hydrological, etc.), of different temporal and spatial scales.

- The realisation that, ultimately, these processes all interact, in a highly non-linear fashion, and that the accuracy of any modelled system ultimately resides in its fidelity to the real world;

- The fact that there is already an increasing societal need for scientifically based scenarios and predictions of environmental change.

Canada is lagging behind the USA and several European countries, where integrated modelling systems have already been designed and implemented for large ecosystems (e.g. Chesapeake Bay). The development of such complex environmental models requires large multidisciplinary teams of highly competent scientists.

These two priorities are tightly coupled, as the data that is needed to drive the models will be accessed using the assimilation techniques mentioned above. The cost for the computing infrastructure is very high, given the need for high spatial resolution. The WEP research program will be pivotal in equipping Canada with the tools needed to develop these complex environmental modelling systems.

5.0 Meteorology and Hydrology

The impacts of extreme weather events on society are becoming increasingly costly in terms of damage to infrastructure, injury, and loss of life. Meteorological research will be focused on reducing impacts through improved detection and more accurate and timely prediction of summer and winter severe weather.

The development and establishment of the Canadian Weather Research Program (CWRP) will be the highest priority activity over the next 3 to 5 years. This program will focus on extreme meteorological events. The CWRP will endeavour to ensure its effort complements that of the World Weather Research Program and the United States Weather Research Program, and will strive to participate in specialised field projects.

The premise of the CWRP is that better understanding of atmospheric processes and advances in modelling, data assimilation, and observing systems will result in more accurate predictions. A measurable reduction in impacts is the ultimate goal. Predictions of precipitation and winter weather, especially in highly populated areas, will be emphasised.

A related priority will be national leadership in science through support for the development of national research institutes and national centres of excellence in areas related to natural disasters and environmental prediction. This will involve developing collaborations within EC, with other government departments, industry (e.g., the insurance industry), and universities. The intention of these collaborations is to ensure the most effective and efficient research and development (R&D) program possible to benefit Canadians. The infrastructure resulting from these partnerships will be used as a platform for training and professional development of Environment Canada (EC) staff. A strong meteorological research program is an essential component for sound prediction capabilities in domains such as air quality and hydrology.

5.1 Research Directions For the Next 3 - 5 Years

Improved Detection and Prediction of Summer and Winter Severe Weather

This will include research in the use of ground and satellite based remote sensors and in-situ data to better detect severe weather phenomena such as tornadoes, strong winds, heavy precipitation (snowfall, rain, hail, freezing precipitation), and transportation hazards (fog, aircraft icing, road icing). This information will subsequently be integrated with numerical models to better understand processes and more accurately predict severe weather phenomena.

Numerical Weather Prediction - Improvements in a unified approach using the Global Environmental Multi-scale Model (GEM) including the development of:

- A non-hydrostatic and distributed memory version of GEM for deterministic and ensemble short and medium range operational weather forecasting, with improved physics, improved surface simulations and statistical post-processing approaches

- A nested non-hydrostatic community version of GEM with scales from less than one kilometre to hundreds of kilometres, for use by the Canadian and international research community

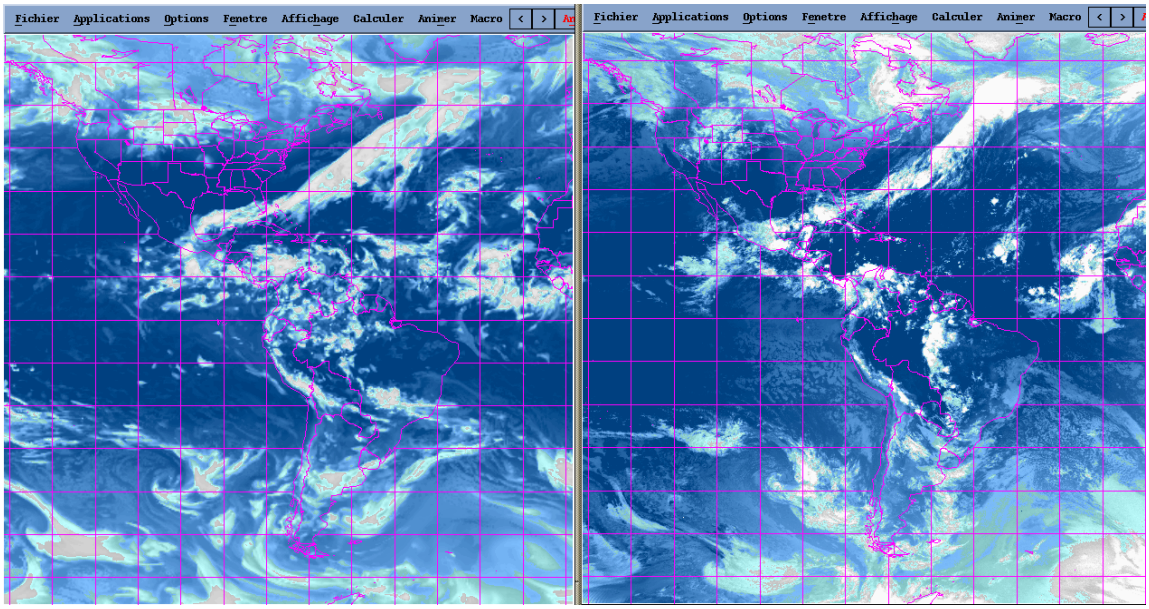
- A middle atmosphere version of GEM for data assimilation, chemical modelling, and observation system simulation experiments

Data Assimilation

The main priority will be to increase the quantity and diversity of data going into the assimilation cycles and to use the data more effectively. The short-term focus will be on raw satellite and conventional data, and the long term focus will be on shifting to the vast amount of new remotely sensed data, like Doppler radial velocities, scatterometer winds and Global Positioning Systems (GPS) for the retrieval of water vapour and temperatures. The strategy will be to implement an updated version of 3D assimilation in the short term, and then move to flow dependent 4D assimilation using variational assimilation and ensemble Kalman filter techniques, and targeted observing strategies.

Another priority will be to use data assimilation and modelling advances to more efficiently manage our observing networks and methodologies. This will become an essential requirement in the next few years given the resource pressures that will continue to be imposed on observing networks.

A prediction from the Global and Environmental Multiscale (GEM) Model:



On the left, 96H prediction of outgoing infrared flux with the experimental uniform grid GEM at 35km horizontal resolution. On the right, the observed outgoing infrared flux.

Environmental Prediction

The priority will be on the development of a coupled version of the GEM model for atmosphere-ocean and atmosphere-hydrology environmental prediction problems, and the use of these capabilities in ecosystem environmental prediction research projects in partnership with EC partners through research co-ordination with the Nature Business Line and others. This will include the development of precipitation accumulation, rate analysis and prediction products for use in hydrological prediction and cryospheric activities such as flood predictions using the WATFLOOD hydrological model and ice layer simulations using the RCM-coupled atmospheric model. In the field of air quality, priority will be on the development of coupled meteorological and air quality models for air quality prediction.

6.0 Climate

Climate change is a major global issue whose impacts are projected to have significant socio-economic and ecological repercussions. Science has established that climate change is taking place. Climate research will be focused on providing improved scenarios of future climatic conditions in order to reduce uncertainties, gain a better understanding of future impacts and develop adaptation strategies. The following four main areas of research activity are contributing to meeting this challenge.

WEP Research Agenda (2000-2005)

Climate Monitoring and Data Interpretation

This activity involves monitoring and analysing the Canadian and global climate in order to document and understand climate trends and variations (including changes in extremes), and to attribute these changes to such causes as global warming, changes in the circulation of the global atmosphere and ocean, and others. It also includes extending the climate record back for 1000 to 2000 years using integrated historical and proxy data sets.

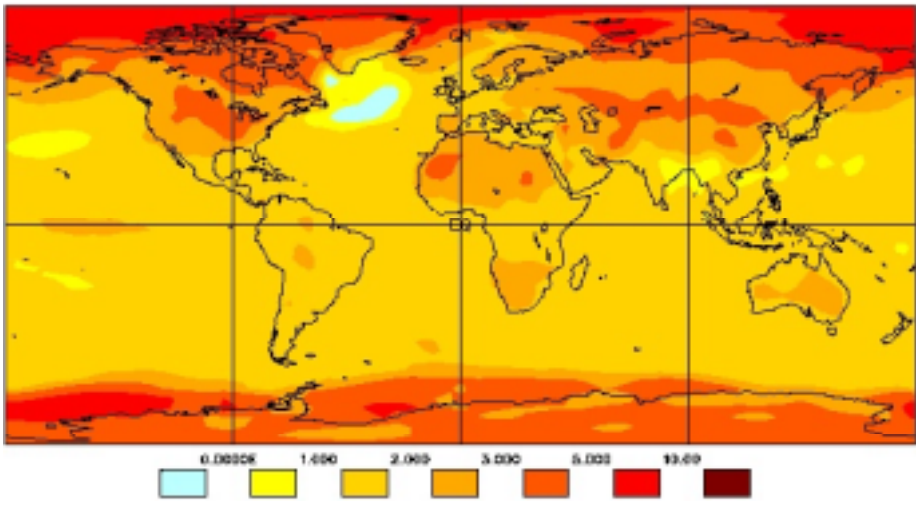
Climate Processes and Earth Observation

This activity involves conducting research to improve our understanding of energy and water cycles and their component processes, particularly in cold climates. It involves the development and implementation of improved remote sensing and field measurement methodologies. Special emphasis is placed on the measurement and modelling of land surface processes within the climate system, and on the evaluation and application of regional climate and weather models as integrating tools.

Climate Modelling and Analysis

This activity involves developing and using sophisticated atmospheric and coupled climate models and advanced analyses of observed data and model output to improve our understanding of present, past and future climates. The models and analysis tools are used in short term climate forecasting, for studies of climate predictability and variability, and to project and analyse the future climate change that will result from the human-induced changes in the composition of the atmosphere.

Surface warming projected by CGCM2 - 2050 vs 1980



6.1 The Climate Research Network

The climate research effort is conducted in partnership with the Canadian academic community through the Climate Research Network. This is a network of nine collaborative research groups, each of which focuses on a specific area of climate research, primarily in support of climate model improvement. The current nodes are:

Regional-scale Climate Modelling	Paleoclimate Modelling
Middle Atmosphere Modelling	Arctic Ocean Modelling
Climate Variability	Carbon Cycle Models
Land-surface Processes	Aerosols and Climate
North Atlantic Regional Canadian Community Model	

The Climate Research Network has resulted in several significant advances in climate modelling, most notably in middle atmosphere and regional climate modelling, in land-surface process understanding, and in climate variability and predictability issues. A key challenge now is to bring the technology and knowledge developed in the network into the Canadian Centre for Climate Modelling and Analysis. The long-term viability of large models like the Middle Atmosphere Model and the Regional Climate Model depends on having an adequate and stable infrastructure to support the models. Such an infrastructure is most suitably located within government. One area of particularly high demand in the coming three to five years will be for climate model results with finer temporal and spatial resolution than is currently available from the global models. The Regional Climate Model is expected to satisfy this demand, which arises mainly from the adaptation and impacts research community.

6.2 Research Directions for the Next 3 - 5 Years

Priorities for the next 3 – 5 years are based on three main considerations.

- The first is an evaluation of the state of climate science as reflected in views from the Intergovernmental Panel on Climate Change (IPCC) and from the World Climate Research Program (WCRP). These bodies provide consensus views on outstanding uncertainties and gaps in our knowledge of the climate system. As partners in these bodies, we are in a position to benefit from and contribute to their overall assessments of the state of the science and their programs of climate research.

- The second consideration is that the needs of Canadians are reflected in the goals and priorities of Environment Canada and the Weather and Environmental Prediction Business Line. These priorities must incorporate the needs of both citizens and government, from both national and regional perspectives.

- The third important consideration is a realistic assessment of the strengths, expertise and resources available.

Below, three areas of research are identified as priorities that require special attention over the coming few years. A fourth is more organisational in nature.

Climate Data Analysis

To examine the many aspects of detection and attribution of climate change, using both cleaned data sets and climate model outputs. An important element of this will be the study of regional-scale climate anomalies in Canada. It will also involve the examination of proxy data.

Regional Climate Change Scenarios

To make effective use of the knowledge and technology developed in the Climate Research Network, specifically for the Middle Atmosphere Model and the Regional Climate Model. In the latter case, to develop the capacity to deliver finer resolution climate model results to satisfy various regional and sectoral needs, primarily for the impacts and adaptation communities.

Cryospheric and Remote Sensing Research

Specific areas in need of expansion are the development and application of satellite methodologies and products to aid in understanding and modelling soil moisture and cryospheric responses to climate change. Activities here will include partnerships with the Canadian Space Agency and the university community in Canada, and involvement in international programs.

National Leadership Role on Climate Science Issues

This will entail working toward a more coherent and co-ordinated climate science program in the Meteorological Service of Canada, for example, through improved measurement techniques for climate variables, climate network design, and seasonal forecasting.

7.0 Atmospheric Chemistry Research

Atmospheric chemistry research focuses on advancing knowledge of the chemistry of the atmosphere, understanding how it is changing, and understanding how these changes are affecting the physical behaviour of the atmosphere. This includes advancing the knowledge of the transport, transformation and deposition of atmospheric pollutants that adversely affect human and natural ecosystems throughout the world. Atmospheric chemistry research provides the scientific basis for policy development (the lead for which resides with the Clean Environment Table), air quality predictions, and adaptation strategies to minimise the potential negative impacts. This research involves conducting systematic observations, studying atmospheric processes, and modelling. It focuses on five main air issues.

7.1 The Five Main Atmospheric Issues

1. Depletion of the stratospheric ozone layer resulting in increased UV flux at the earth's surface

2. Greenhouse gases, aerosols and surface radiation related to climate change

3. Acidifying deposition and oxidants leading to acidification of ecosystems and increases in photochemical smog

4. Fine particulate matter and aerosols affecting human health

5. Hazardous air pollutants that impact on ecosystems such as the Great Lakes and the high Arctic

<u>Stratospheric Ozone and Space Research</u>

Stratospheric ozone and space research contributes to the understanding of the behaviour of stratospheric ozone in order to identify and measure the changes attributable to human activities, and to study the causes and effects of such changes. The program includes the measurement of stratospheric ozone and other relevant trace gases, the dissemination and archiving of the data, and the interpretation and evaluation of the results.

The stratospheric ozone depletion problem is a long-term issue. Stratospheric ozone has been studied for 40 years and the depletion problem emerged only in the past two decades. Causes of depletion were identified and legislation was developed to reverse the effect. It is expected, with all other influences remaining constant, that it will take at least another decade before a reversal of the downward trend in ozone will be detected, and then several more decades for ozone to gradually return to normal levels.

Many of the stratospheric ozone studies have been conducted by installing instrumentation on satellites and the space shuttle. There are a number of atmospheric science issues that can be approached using data collected from space platforms. The experience gained from the stratospheric ozone space-based experiments provides a basis for the design and application of space instrumentation to address other atmospheric issues.

Greenhouse Gases, Aerosols and Surface Radiation Research

This research contributes to our understanding of greenhouse gases (and their isotopes), aerosols, and changes in the surface radiation budget as they relate to climate change. Increases in the concentrations (mixing ratios) of these gases and aerosols in the atmosphere directly alter the spectral and spatial distribution of energy in the earth-atmosphere system. It is these changes that alter the overall climate system.

Acidifying Deposition and Oxidants Research

This research program is an amalgamation of the former acid deposition and NOx/VOC science programs. The oxidising capacity of the atmosphere was the focus of the NOx/VOC science plan, and is also central in determining the production of acidifying material. In addition to atmospheric transformation processes, oxidants and atmospheric acidity are linked through having common emission sources and being subject to similar transport, transformation and deposition processes.

Particulate Matter / Aerosol Research

Suspended particulate matter (PM) or aerosols play a prominent role in human health, smog, toxics, climate, ozone depletion and acid rain issues. Recently, federal initiatives to establish air quality objectives for airborne particulate matter of less than 2.5 micrometers (PM2.5) and 10 micrometers (PM10) has increased the urgency of being able to measure and forecast these parameters in Canada. Aerosols are comprised not only of primary particles emitted directly to the atmosphere, but also of products from gas-to-particle conversion (sulphur oxides, nitrogen oxides, volatile organic compounds, and semi-volatile organic compounds) in clear air and clouds. Thus, considerable research is needed to better understand the complex processes of formation, transport and deposition.

Hazardous Air Pollutants Research (HAPs)

This research program has as its overall objective to understand and predict the environmental cycling of air toxics with the intent of providing advice and guidance to reduce risks to human health and the environment. The research efforts are targeted at a better understanding and prediction of the behaviour of hazardous air pollutants. This includes consideration of the emissions, transport, transformation, distribution and deposition of the chemicals in question. For the purpose of this research program, hazardous air pollutants are generally viewed as being members of the classes of moderate to low volatility organic compounds and also some trace elements. Many of these organic compounds contain chlorine, are industrial chemicals, products of combustion, or are intentionally created as pesticides or herbicides. The program is focused on two regional programs (Great Lakes, Arctic) and one national program (Mercury in the Environment).

7.2 Research Directions for the Next 3 to 5 years

Priorities for the next three to five years are based on the following considerations:

- The major current atmospheric environment policy issues will remain and continue to demand scientific research.

- The foci of concerns will evolve as we gain a better understanding of the issues and actions taken. For example, there are now more clearly articulated health concerns associated with particulate matter that is formed by the acidification process and how such particulate matter is involved in the issue of toxic chemicals in the atmosphere.

- Data assimilation, numerical simulation, and prediction techniques can presently be applied to air quality issues in appropriate spatial and time scales to adequately address these important issues.

The following three areas of research have been identified as the key areas of focus over the next 3 to 5 years. The fourth area is part of the strategy for achieving these goals.

Systematic Observations

Long-term measurement programs to detect changes in atmospheric composition and to determine long-term trends will be maintained and enhanced through the development of new technologies. The emphasis will be on a CORE network of about six stations that will represent the different atmospheric chemical regimes in Canada. The measurements will also include the development and use of space-based technologies.

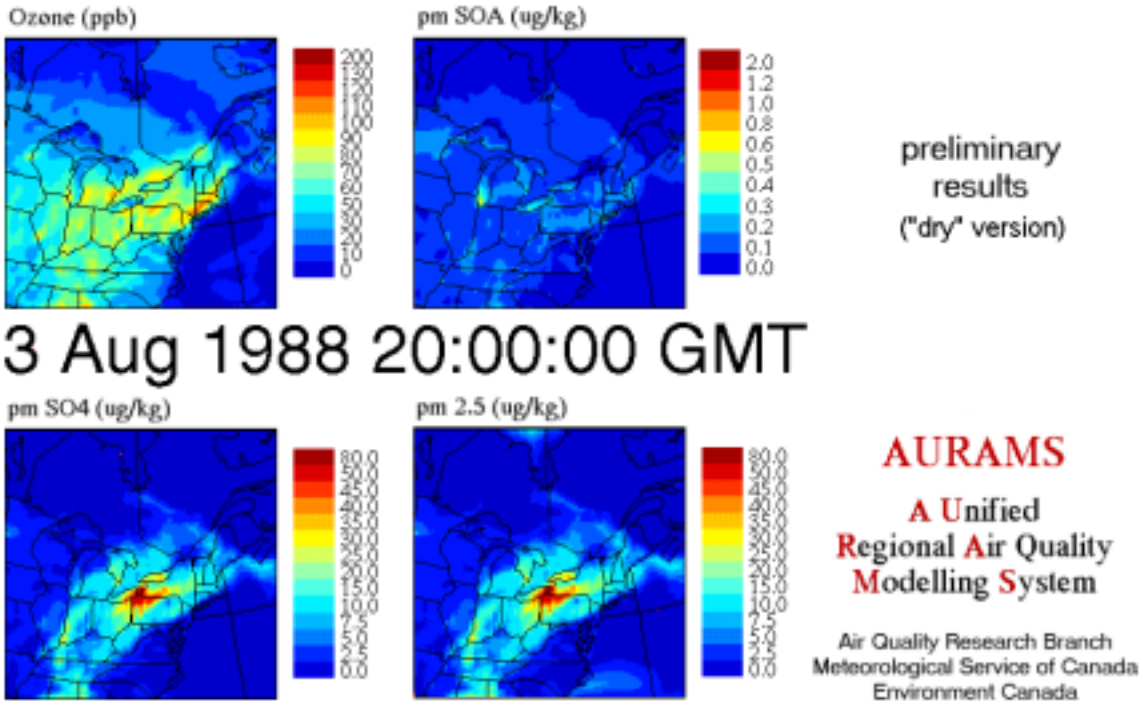
Atmospheric Chemical Processes

An emphasis will be placed on the chemical characterisation and specialisation of selected air toxics and fine particulate matter.

Air Quality Prediction

An emphasis will be placed on the development of a unified air quality model (including fine particulate matter), coupled to meteorological models to address policy needs and environmental prediction. Developing the capability to apply the models to specific policy and information requirements will also be emphasized. This air quality predictive capability will be used to provide guidance to the agencies that issue smog advisories to susceptible populations, enabling them to take appropriate action.

A preliminary air quality prediction from AURAMS



National Leadership on Atmospheric Chemistry Research

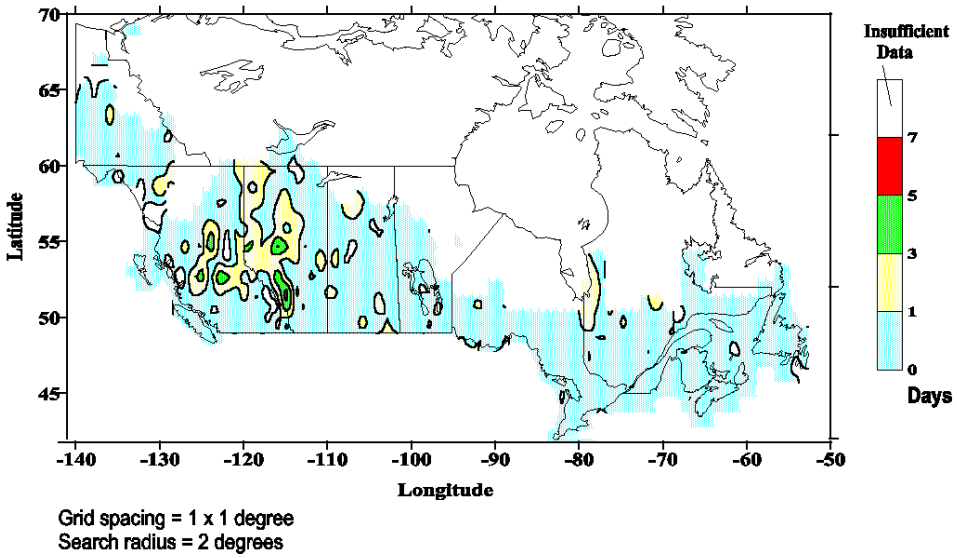
This will involve establishing a research network to increase collaboration with universities and other atmospheric scientists across Canada, to build our scientific capacity and to show leadership within the atmospheric community related to air quality.

8.0 Adaptation and impacts

The adaptation and impacts research program focuses on identifying and assessing the potential ecological and socio-economic impacts resulting from meteorological stresses. It also researches the viability of adaptation options and strategies that could be used to address these impacts. The meteorological stresses that are covered within this research are weather, climate, and air quality and the associated variability and extremes. The resulting research is used regionally, nationally and internationally to enhance scientific understanding, to provide advice to policy makers and to direct service development. The following are the three main areas of activity contributing to this research.

The following map shows the frequency of hail days across Canada. It is an example of a study carried out to identify and assess socio-economic impacts of meteorological stresses.

Hail Frequency Map (May – September, 1977 – 1993)



Impacts and Adaptation Science

The focus will be on advancing impacts and adaptation science by developing methodologies through case studies. This includes improving impact research methods to identify and evaluate adaptive options, and improving research in areas relating to the costs, benefits, and opportunities afforded by atmospheric change and variability.

Impacts and Integrated Assessment

Integrated assessments involve combining knowledge from a variety of disciplines to study the impacts of atmospheric change on natural and social systems. The focus will be on identifying the impacts of atmospheric change and variability on Canada's water resources, human health and urban environments.

National Leadership on Impacts and Adaptation Science

This will involve working toward a more coherent and co-ordinated impacts and adaptation science program by providing the guidance and tools to improve research methodologies and opportunities for collaborative research at the regional, national and international levels.

8.1 Priorities for the Next 3 - 5 Years

Impacts and Adaptation Science

- Supporting the development and improvement of methodologies for the use of scenarios by impact and adaptation researchers. This includes the establishment of the Canadian Climate Impacts Scenarios facility with the support of the Climate Change Action Fund, and definition and maintenance of the facility post-CCAF

- Developing research methodologies for identifying the costs associated with impacts and adaptation strategies, and for identifying how factors that affect adaptive capacity can be determined and how adaptive capacity in Canadian regions and sectors can be strengthened.

Impacts and Integrated Assessment

- Developing methodologies and enhancing research capacity to undertake a national assessment of the impacts of climate change and variability, and mitigating adaptations. This will require engaging the national and international impacts and adaptation research communities for both comprehensive and 'fast-track' assessments.

- Building a national impacts and adaptation co-operative research effort within the Meteorological Service of Canada and the five natural resource departments of the federal government, by establishing partnerships with appropriate academic and research organisations, the regional offices of the MSC, professional societies, and the private sector.

National Leadership on Impacts and Adaptation Science

- Building linkages with and encouraging Canadian involvement in key international impacts and adaptation research efforts such as the US National Assessment, UK Climate Impacts Program, United Nations Environment Program, and the Intergovernmental Panel on Climate Change (IPCC).

- Contributing to the Canadian Weather Research Program by investigating the socio-economic impacts of specific extreme weather events, assessing the cost/benefits of the Canadian weather services and identifying the value of the Canadian weather radar capital investment.

9.0 Partnerships

As noted in section 3, in the next three to five years significant attention will be given to creating multidisciplinary (e.g. Branch / Service / Region) project teams to tackle complex environmental problems. There are limitless possibilities in the types of interactions and partnerships that can be fostered. Below are just a few examples of some of the on-going interactions within the WEP research program that will be continued and nurtured.

- Atlantic Environmental Prediction Research Initiative (AEPRI), a successful partnership between the Atmospheric and Climate Science Directorate (ACSD), Atlantic Region and others.

- St. Laurent Vision 2000 Action Plan, a federal / provincial water level ecosystem study involving Quebec Region, Atmospheric and Climate Sciences Directorate, Fisheries and Oceans Canada, the Ministère de l'environnement du Quèbec, and the Wildlife and Parks Sector.

- Toronto Niagara Region Study (TNRS), a collaborative study between Ontario Region, Atmospheric and Climate Science Directorate, Grand River Conservation Authority, Toronto Region Conservation Authority, and the Ontario Ministry of Environment.

- Mackenzie GEWEX Study (MAGS), an important Canadian contribution to the World Climate Research Program involving Prairie and Northern Region, Atmospheric and Climate Science Directorate, the National Water Research Institute, and several Canadian universities.

- Pacific 2001, involving Pacific and Yukon Region, Environmental Protection Service, Atmospheric and Climate Science Directorate, the Greater Vancouver Regional District and others.

Many other partnership activities are detailed in Section 10.1, Appendix 1.

10.0 Appendices

10.1 Appendix 1- Partnerships

Current WEP partnerships ongoing between the Regions, Services, Directorates, Branches, universities, provincial departments, and other research institutes, private or public are detailed below by Region.

Atlantic Region Partnerships

- The Atlantic Environmental Prediction Research Initiative (AEPRI)

Atlantic Environmental Prediction Research Initiative (AEPRI) is a successful partnership between Atlantic Region and the Atmospheric and Climate Science Directorate (ACSD) in collaboration with other government, industry, and academic partners.

This initiative involves research and development for environmental prediction based on coupling a variety of numerical prediction models. In the past year significant progress has been made in projects particularly in collaboration between the Meteorological Service of Canada and the Oceanography Department of Dalhousie University. The main ongoing coupled modelling and AEPRI sub-projects are:

Atmosphere-ocean coupling via the NSERC/MARTEC/AES Industrial Research Chair in "Regional Ocean Modelling and Prediction" in the Oceanography Department at Dalhousie, coupling data assimilation and prediction systems for coastal applications, modelling the extratropical transition of hurricanes and typhoons, coupled atmosphere-wave models, coupled atmosphere-hydrology models, coupling with estuary models, and developing expert systems for marine applications. Numerous Environment Canada (EC) scientists have gained valuable experience and made significant progress in projects in the areas of storm surge prediction, improved oil spill trajectory modelling, wave-modelling, severe weather prediction, and streamflow prediction (including preparing some new and innovative forecast products which are on the point of becoming operational).

AEPRI has advanced to the point where it will soon become even more inter-disciplinary and provide an opportunity to integrate activities amongst the following EC sectors:

- *The 'SLICK' oil spill model is being used to give support to a project that studies birds oiled at sea*
- *The prediction and mitigation of coastal flooding*
- *A coupled atmosphere /ocean / biological / chemical observing and prediction system to study pollution in coastal inlets*

- The Atlantic Environmental Research Network (AERN)

This network enhances the capacity, efficiency, and application of environmental science in the Atlantic Provinces by establishing a broad interactive network of government agencies and universities to implement cooperative environmental strategies and to capitalize on funding and partnership opportunities in a systematic and coordinated manner.

The network aims are:

- *To undertake high quality fundamental and applied research, within specified areas of interest;*

- *To provide mechanisms to ensure effective linkages between the researchers and the supporting agencies that are faced with making practical environmental and conservation decisions;*

- *To provide a vehicle for enhanced education and training for students, and for scientific interchange among institutions.*

- *To develop three important themes in the short term*
  1. *Wildlife ecology and biological diversity*
  2. *Freshwater and estuarine ecosystems*
  3. *Adaptation and response to climate change impacts.*

Plans and visions:

- *The development of advanced, coupled numerical modelling systems by incorporating improved model components in the prototype system. These modelling systems will be used to study extreme weather events including the extratropical transition of hurricanes, climate change impacts on sea level, and coastal pollution.*

- *The development of a coupled atmosphere/ocean/biology/chemistry ecosystem model to be used to study Lunenburg Bay NS (where we plan to establish an atmosphere/ocean observing and prediction demonstration project. We are awaiting a decision from the Canadian Foundation for Innovation on a proposal for infrastructure funding for a Marine Environmental Prediction System for Lunenburg Bay.)*

- *Partnering in establishing a Centre for Marine Environmental Prediction (CMEP) at Dalhousie University to pursue marine environmental prediction research and development that will be guided and tested using advanced observing systems.*

Quebec Region Partnerships

- St. Laurent Vision 2000 Action Plan, a federal / provincial water level ecosystem study Quebec Region, the Atmospheric and Climate Science Directorate, Fisheries and Oceans Canada, the Ministère de l'environnement de Quèbec, and the Wildlife and Parks Sector.

- St. Laurent Gulf and Estuary Modelling Study (ice layer)

  The purpose of this study is to understand how the St. Laurent Gulf and Estuary will behave under a $2XCO_2$ scenario. The aim is to simulate ice layer thickness using the regional climate model coupled with an atmospheric model. The oceanic model for the St. Laurent region is from the Department of Fisheries and Oceans in co-operation with the University of Alaska (specifically for ice cover).

  The Partners in the project are the Department of Fisheries and Oceans, CERCA, Quebec Region, and ACSD in collaboration with the University of Alaska.

Ontario Region Partnerships

- Integrated Mapping Assessment Project (IMAP)

  The objective of IMAP is to link atmospheric and environmental change issues. IMAP has been engaged in collecting published maps on topics such as climate, severe weather, air quality, human health, woodlots, wetlands, wildlife, land-use, and roads etc. These maps are then functionally linked and integrated by scale according to specific issues, such as climate change, land use change and biodiversity.

  Partners include Ontario Region, the Environmental Conservation Service, the Atmospheric and Climate Science Directorate and the University of Toronto.

- Atmospheric Change and Biometeorology

  Collaborative work between Ontario Region and the Atmospheric and Climate Science Directorate is done to develop research assessments of the linkages between atmospheric change, biotic responses, ecosystems, biodiversity, human health and biotechnology. These assessments provide input to IMAP and to the World Meteorological Organization (WMO), International Society of Biometeorology Commission on "Biometeorology Requirements for Adaptation to Climate and Biodiversity Variability and Change".

- Greenhouse Gas Reduction Co-Benefits

  This is a project to assess the collateral benefits of reductions in green house gases to air quality, human health and ecosystems, using qualitative approaches, including expert judgment.

  Partners include Ontario Region and the Atmospheric and Climate Science Directorate, Pollution Probe and the Rainmakers Environmental Group.

- Sustainable Communities

  Collaborative work between Ontario Region and the Atmospheric and Climate Science Directorate, and NRCan-Sustainable Community Program is carried out to develop information that can be applied locally to support decision-making for sustainable communities (e.g. meteorological hazard risk maps, regional climate change sensitivities).

- Toronto-Niagara Region Project

  Toronto Niagara Region Study (TNRS), a collaborative study between Ontario Region, Atmospheric and Climate Science Directorate, Grand River Conservation Authority, Toronto Region Conservation Authority, and the Ontario Ministry of Environment.

- Air Quality Prediction Program

  Partners include Ontario Region, other the Meteorological Service of Canada Regions and the Atmospheric and the Climate Science Directorate (ACSD). Partnership is projected to grow in the near future. Current regional involvement includes the assessment of SAQP, CHRONOS tools with recommendations for improvements.

- MC2 Modelling Community

  Ontario Region supports development of mesoscale modelling applications to air quality through university contract work. This work is made available and co-ordinated through the Atmospheric Environmental Prediction Directorate.

Prairie and Northern Region (PNR) Partnerships

- The Mackenzie GEWEX Study (MAGS)

  The Mackenzie River is the largest North American source of freshwater for the Arctic Ocean. This basin is subjected to wide fluctuations in its climate and it is currently experiencing a pronounced warming trend. As a major Canadian contribution to the Global Energy and Water Cycle Experiment (GEWEX), the Mackenzie GEWEX Study (MAGS) is focusing on understanding and modelling the fluxes and reservoirs governing the flow of water and energy into and through the climate system of the Mackenzie River Basin. (MAGS) necessarily involves research into many atmospheric, land surface, and hydrological issues associated with cold climate systems. This research and development is being conducted as a partnership between university and government researchers with support from NSERC, ACSD, Prairie and Northern Region, and some private industries.

- Air Quality Research Partnering in PNR

  Monitoring of atmospheric mercury in PNR's oilsands area and at CAPMoN site, Esther, Alberta. Partners are PNR and the Atmospheric and Climate Science Directorate.

- Prairie and Northern Region (PNR) is working in co-operation with the Atmospheric Environmental Prediction Directorate on mesoscale modelling development and tuning.

- PRISM

  A proposal has been submitted to apply the PRISM (Parameter-elevation Regressions on Independent Slopes Model) analysis tool to generate gridded climate maps of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, snowfall, degree days, and dew point for the prairies for use in climate change and impact studies.

Pacific and Yukon (P&Y) Partnerships

- Risk of erosion and flooding in BC

  Partnership between Pacific and Yukon Region (P&Y) with the Department of Fisheries and Oceans (DFO) Canadian Hydrographic Service, under the auspices of Canadian Climate Action Fund. This is a study of the coastal impacts of sea level rise and weather.

- Canadian Weather Research Program

  Pacific and Yukon Region (P&Y) participate in this project under the overall direction of Atmospheric and Climate Science Directorate. This program addresses the need to identify areas of priority research based on societal needs that will most effectively result in improved prediction and a reduction of impacts due to extreme weather.

- The Hemispheric Observing System Research and Predictability Experiment.(THORPEX)

  Targeted observations using low-cost robotic aircraft (aerosondes) under the auspices of THORPEX. The project lead is the Meteorological Research Branch of the Atmospheric and Climate Directorate with collaborators being the Atmospheric Environmental Prediction Directorate, the Monitoring and Water Survey Directorate and Pacific and Yukon Region (P&Y). The objectives of this project are to conduct R&D to improve identification of target areas and assimilation of targeted observations and to develop an aerosonde deployment strategy pre-THORPEX.

- GeoInnovations Envirodat Spatial Catalogue

  A collaborative project between Pacific and Yukon Region (P&Y) and Ground Control under the auspices of the Natural Resources Canada GeoConnections Initiative. The objective of this project is to develop a web-based system for accessing enhanced meta data for climate, hydrometric and water quality data sets in Pacific and Yukon Region (P&Y).

- Pacific 2001

  This collaborative field study is aimed at gathering detailed measurements on the physical and chemical characteristics of fine particulate matter in the Lower Fraser Valley air shed. The measurements will be using to evaluate and initialize atmospheric computer models to assess air shed management strategies. Planning for the study is currently underway with the study proposed for September 2001. Partners include the Atmospheric and Climate Science Directorate (ACSD), York University, the University of British Columbia, the University of Washington, the University of Victoria, Royal Roads University, the British Colombia Ministry of Environment, Lands and Parks, Greater Vancouver Regional District (GVRD), and the Fraser Valley regional District (FVRD).

- Daily Air Quality Forecasts

  Daily forecasts of ground level ozone concentrations are being disseminated to partner agencies through the *SMOG* season in the Lower Fraser Valley (May through September) as part of a pilot project. Partners include Greater Vancouver Regional District (GVRD); FVRD; British Columbia Ministry of Environment, Lands and Parks and the Northwest Air Pollution Authority for Whatcom County.

- Mesoscale Meteorological Modelling

  The application and development of the MC2 Model to Southwestern British Columbia is underway to provide high resolution meteorological fields to support ecosystem studies and support complex atmospheric chemistry models (e.g. predicting ground level ozone, fine particulate matter). Partners include the University of British Columbia (Atmospheric Science Program) and the Atmospheric Environmental Prediction Directorate.

- Metals in the Environment

  A mercury measurement project is underway to quantify the total gaseous mercury and the wet deposition of mercury in the western regions of the Lower Fraser Valley. This is as part of an international effort to understand the distribution of atmospheric mercury and subsequent loadings to receiving environments; partners include the Atmospheric and Climate Science Directorate (ACSD); US MDN; P&Y.

- Climate Variability
  How climate variability in British Columbia and the Yukon are linked to the Pacific Decadal Oscillation and ENSO will be analyzed; partners include the Pacific and Yukon region and the Atmospheric and Climate Science Directorate (ACSD).

- Climate Trends
  Trends in temperature and precipitation extremes during the 20th century will be analyzed at selected climate locations in British Columbia and Yukon next fiscal year.
  Partners include Pacific and Yukon Region and the Atmospheric and Climate Science Directorate (ACSD).

- Environmental Prediction Decision Support System (EPDSS) for Reservoir Management for Greater Vancouver Regional District (GVRD)

  This is the third year of a multi-year collaborative research study. The objective is to research and develop integrated watershed hydrological models for reservoir management using hydrological models such as WATFLOOD and AGNPS and reservoir hydrodynamic models such as TELMAC and SEDSIM. Partners: Hydrology Research and), Applications and Services Division of MSC-Pacific and Yukon Region, the Canadian Hydraulics Centre of the National Research Council and the National Water Research Institute of the Environmental Conservation Service.

Meteorological Service of Canada (MSC) Directorate Partnerships

- The Canadian Meteorological Centre (CMC) now re-named as the Atmospheric Environmental Prediction Directorate (AEPD) has had and continues to have a strong interactive relationship with the Meteorological, Climate and Air Quality Research Branches of the Atmospheric and Climate Research Directorate (ACSD) in research and operations. AEPD operates the supercomputer that is an essential tool for all environmental prediction related research. AEPD regularly transfers technological advances in support of ACSD's data assimilation systems and prediction models used for environmental prediction. Many improvements to Numerical Weather Prediction in its broadest sense have been accomplished through this partnership. The CANERM model (for environmental emergency response related to nuclear explosions) and the air quality prediction program are examples of collaborations between ACSD branches and AEPD.

- A number of collaborative projects are planned to focus on the design of the weather observation network and targeting strategies that will involve the Atmospheric and Environmental Prediction Directorate (AEPD), the Atmospheric and Climate Science Directorate (ACSD), the Atmospheric Monitoring and Water Survey Directorate (AMWSD), and the Regions as partners. This is projected to happen within the next 5 years.

- Global Energy and Water Cycle Experiment on the Mackenzie Basin (GEWEX-MAGS)

  Canada is a major contributor to the international Global Energy and Water Cycle Experiment (GEWEX) developed by the World Climate Research Program (WCRP). The Mackenzie GEWEX Study (MAGS) is one of six continental scale GEWEX investigations. The primary focus of the MAGS is understanding and modeling the flow of water and energy into and through the Mackenzie Basin Cold Region Climate System, and related changes to the water resources. Strong collaborations have been fostered between

investigators from governmental institutions (e.g. National Water Research Institute, the Atmospheric and Climate Science Directorate, Prairie and Northern Region (PNR), and Universities (e.g. McMaster, McGill, Waterloo, Toronto, York, Saskatchewan, Quebec at Montreal, Dalhousie, Colorado) and others.

- International Atmospheric Deposition Network

  The United States Environmental Protection Agency in co-operation with the Atmospheric and Climate Science Directorate and Ontario Region perform atmospheric monitoring to determine atmospheric deposition loadings of toxic air pollutants to the Great Lakes.

- Coupled Hydrological Modelling

  The Meteorological Research Branch (MRB) models are coupled with the University of Waterloo's WATFLOOD hydrological model. With radar or atmospheric model precipitation inputs, WATFLOOD outputs compare favourably with measured stream flow for southern Ontario.

- Climate Research Network (CRN)

  Partners: The Atmospheric and Climate Science Directorate (ACSD), University of Victoria, Canadian Institute for Climate Studies (CICS) and 12 Canadian Universities.

  This research collaboration supports research in climate science in Canada, primarily to advance climate modelling, as well as the development of young scientists in this field. Currently the network has nine nodes.

- Climate Coordinating Committee (CCC)

  Partners: The Atmospheric and Climate Science Directorate (ACSD), The Atmospheric Monitoring and Water Survey Directorate (AMWSD), and all Environment Canada Regions.

  This group oversees climate science activities planned and carried out within the Meteorological Service of Canada.

- Canadian Contributions to the World Climate Research Program (WCRP)

  Partners*:* The Atmospheric and Climate Science Directorate (ACSD), EC Regions, Canadian Universities, The Department of Fisheries and Oceans (DFO), and international universities and agencies

Meteorological Service of Canada (MSC) scientists are involved in several of the WCRP research projects through participation in field and modelling studies such as the Mackenzie GEWEX Study (MAGS) and the new Climate and Cryosphere Program (CLIC), and several climate model intercomparisons such as AMIP and CMIP. In most cases, these involve government, university, and foreign scientists.

Multi-Regional Partnerships

- Special collaborative research studies are on going and planned for in the future between the Atmospheric Environmental Prediction Directorate (AEPD), the Atmospheric and Climate Science Directorate and various Regions. These studies are aimed at studying the benefits of very high-resolution model outputs over pre-selected regions. In 2000, such a project was run with Pacific and Yukon Region (P&Y) and Prairie and Northern Region (PNR). Others similar studies are planned for the other Regions.

- CORE Measurement Program
  The purpose of this program is to determine the long-term changes of atmospheric constituents and radiation in five major Canadian airsheds. It is a collaborative program between the Atmospheric and Climate Science Directorate (ACSD) and the Regions. The CORE sites are:

  1. *Alert /Eureka in the Arctic*
  2. *Saturna on the Pacific Coast*
  3. *Bratt's Lake on the Prairies*
  4. *CARE, Egbert, in Ontario's industrialized East*
  5. *St.Anicet, Quebec, in the Industrialized East*
  6. *Kejimkujik on the Atlantic Coast*

- The Canadian Air and Precipitation Monitoring Network (CAPMoN)

  The Canadian Air and Precipitation Monitoring Network is a non-urban air quality monitoring network with siting criteria to ensure that measurement locations are regionally representative. There are currently 19 measurement sites in Canada and 1 in the United States. The objective of the network is to determine the spatial patterns and temporal trends of atmospheric pollutants related to acid rain and smog, and to study atmospheric processes.

- The Canadian National Atmospheric Chemistry (NatChem) Database and Analysis System

  The purpose of NatChem is to support atmospheric research through the archival and analysis of North American air and precipitation chemistry data. NatChem is comprised of 3 databases for precipitation chemistry, particulate matter and air toxics (e.g. ground level ozone). This program is managed and maintained by the Atmospheric and Climate Science Directorate.

- PRISM

  A proposal has been submitted to apply the PRISM (Parameter-elevation Regressions on Independent Slopes Model) analysis tool to generate gridded climate maps of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, snowfall, degree days, and dew point for the prairies for use in climate change and impact studies.

Canadian Ice Service Partnerships

- Co-operative Interdisciplinary Cyrospheric Experiment (C-ICE) - a multi-year study of the relationship of physical, chemical and electromechanical properties of sea ice and snow cover and the signatures acquired from remotely-sensed data. Collaborators – Canadian Ice Service (CIS)/Centre for Earth Observational Science (CEOS) -University of Manitoba/National Research Council(NRC)/Canadian Coast Guard (CCG)/Natural Resources Canada (NRCAN)

- Implementation of techniques for monitoring decay and break-up of sea ice through remote sensing techniques. Work is being done through a funded New Search and Rescue Initiative (NIF) project. Collaborators - CIS/University of Manitoba/ Department of National Defence (DND) Search and Rescue/CCG

- Study of changes to sea ice extents with a view to projecting future ice regimes under change scenarios. Work being funded under two Climate Change Action Fund (CCAF) projects:

  - *"The State of the Arctic Cryosphere during Extreme Warm Summer of 1998: Documenting Cryospheric Variability in the Canadian Arctic for Assessing the Significance of Recent Warming" and,*
  - *"Sea Level Rise and Climate Change: Impacts and Adaptation Needs Prince Edward Island: A Case Study." Collaborators: CIS/Meteorological Service of Canada (MSC) Atlantic/Canadian Climate Research Program (CCRP)/Geological Survey of Canada (GSC)/University of Waterloo*

- Evaluation and applications development for new satellite-based remote sensors (**RADARSAT2**, **ENVISAT**, **ASAR** - Advanced Synthetic Aperture Radar, **ALOS** – Advanced Land Observing System, etc). Collaborators: CIS/Canadian Space Agency (CSA)/European Space Agency (ESA)/Canadian Centre for Remote Sensing (CCRS)/National Ice Centre (NIC)/CCG

- Detection and identification of icebergs from satellite-based SAR. Funded through Office of Energy Research and Development (OERD)/ Panel on Energy Research and Development (PERD). Collaborators: CIS/OERD/International Ice Patrol(IIP)/C-CORE

- Development of algorithms for information extraction from remotely-sensed data (**ARKTOS** – Advanced Reasoning using Knowledge for Typing of Sea ice, ice classification, ice tracker, ice temperature). Collaborators: CIS/NIC/CCRS/University of Kansas

- Implementation of coupled ice-ocean models for ice prediction. Funded through OERD/PERD. Collaborators: CIS/DFO-Bedford Institute of Oceanography (BIO)- Institute Maurice Lamontagne (IML)/OERD/CCG

- Development of new iceberg drift and deterioration model. Funded through OERD/PERD. Collaborators: CIS/IIP/OERD

Future Research and Development Directions

- Prediction tools for long-range (out to 6 months) forecasting of freeze-up and break-up

- Development of tools and algorithms for the remote detection of parameters such as: ice thickness, ice pressure, ice strength, and ridge statistics

- Understanding the linkage among climate change, sea ice extent and thickness, and resultant impacts upon navigation and human activity in the north

- Development of data fusion techniques for the extraction of ice information from a variety of remotely sensed data sources

- Assimilation of remotely sensed data into high-resolution ice models