Environment Canada | Environnement Canada

Meteorological Service of Canada

2001 PEER REVIEW
Research & Development Program

Canada

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ACSD	Atmospheric and Climate Science Directorate
AIRG	Adaptation and Impacts Research Group
AMWSD	Atmospheric Monitoring and Water Survey Directorate
AQRB	Air Quality Research Branch
AURAMS	A Unified Regional Air Quality Modelling System
BERMS	Boreal Ecosystem Research and Monitoring Sites
BEST	Building Excellence in Science and Technology
BOREAS	Boreal Ecosystem–Atmosphere Study
CAPMoN	Canadian Air and Precipitation Monitoring Network
CCCma	Canadian Centre for Climate Modelling and Analysis
CE	Clean Environment
CFCAS	Canadian Foundation for Climate and Atmospheric Sciences
CLASS	Canadian Land Surface Scheme
CMC	Canadian Meteorological Centre
COMET	Cooperative Meteorology Education and Training
CRB	Climate Research Branch
CSTA	Council of Science and Technology Advisors
CWRP	Canadian Weather Research Program
EC	Environment Canada
EKF	Ensemble Kalman Filter
EPA	Environmental Protection Agency
EPS	Environmental Protection Service
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEM	Global Environmental Model
HAPS	Hazardous Air Pollutants
IPCC	International Panel on Climate Change
MAGS	Mackenzie GEWEX Study
MRB	Meteorological Research Branch
MSC	Meteorological Service of Canada
NCEP	National Centers for Environmental Prediction
NDSC	Network for the Detection of Stratospheric Change
NWP	Numerical Weather Prediction
ODS	Ozone Depleting Substance
PM	Particulate Matter
POPs	Persistent Organic Pollutants
R&D	Research and Development
RDMQ™	Research Data Management and Quality Control System
RPN	Recherche en Prévision Numérique
S&T	Science and Technology
SAIB	Science Assessment and Integration Branch
WEP	Weather and Environmental Prediction
WMO	World Meteorological Organization

1. INTRODUCTION

Throughout the scientific community it is accepted that regular review of accomplishments and plans by a panel of external experts is a valuable mechanism for establishing future goals and priorities. External review is explicitly identified by the Council of Science and Technology Advisors (CSTA) as a means of ensuring excellence in science and technology (S&T) performed by the Government of Canada.

This review of the Meteorological Service of Canada's (MSC) research and development (R&D) activities was undertaken at a particularly opportune point in time. Occurring on the heels of significant resource reductions associated with *Program Review* and the reallocations of *Living Within Our Means*, the results of this review should provide meaningful input to the forward-looking *Focusing on the Future* exercise.

To undertake the review, a panel of international experts was assembled. The panel was invited to review all aspects of MSC R&D with particular emphasis on excellence, relevance and impact of the science, and to provide an assessment and recommendations to senior management. The structure of the panel included several sub-panels, each with a particular area of expertise, and an overall panel chair, Dr. Elbert (Joe) Friday. A list of panel members and relevant biographical information are provided in Appendix A of this report.

In conducting the review, the panel was provided with lists of publications and citations and a summary of accomplishments for each branch of Atmospheric and Climate Science Directorate (ACSD). Reference material included all relevant research agendas, strategic plans and business plans for MSC and for the Weather and Environmental Prediction (WEP) and the Clean Environment (CE) business lines. Information on related MSC Regional research activities was either available through prepared summaries or through telephone interviews. Results from surveys of clients/partners/stakeholders were also provided as background material.

In addition to studying background material, the panel and sub-panels conducted on-site visits. These visits allowed for highly informative exchanges between panel members and a wide range of national and regional MSC managers and scientists as well as external collaborators, clients and peers. Appendix B provides a listing of presentations and interviews conducted during the on-site visits. Informal discussions were also undertaken by the panel chair with several other individuals within and outside of MSC.

Following the review of the three major MSC R&D initiatives, a similar review of MSC sea ice R&D was undertaken. The sea ice review was completed and the report available in time to be included with this report. The report of the sea ice R&D review appears as Appendix C.

Inquiries concerning the MSC R&D review can be directed to Mr. Adam Fenech, Science Advisor to the Director General of ACSD at adam.fenech@ec.gc.ca, or 416-739- 4267.

2. OVERVIEW OF PANEL FINDINGS

2.1 Background

Climate and climate change are strategically important to Canada. Much has been learned during the past two decades about the changes anticipated in the global climate as a result of the increasing levels of greenhouse gasses in the atmosphere. The changes are expected to be felt first in the more poleward latitudes, and will have major impacts on Canada. Even with all that has been learned, however, many important questions have yet to be answered, including the nature and scope of the regional changes and the response of the Canadian climate to many of the adaptation and mitigation strategies under consideration. Definitive understanding of climate change impacts on ecosystems, air quality, and water quantity and quality is still in its infancy.

Air quality has been, and continues to be, a major issue for Canadians. As a result, Canada has been a world leader in the associated sciences. The same science base that supports the air quality research is also relevant to other issues such as the transport and diffusion of hazardous materials related to anti-terrorism activities.

The citizens of Canada are subject to a wide variety of severe and routinely disruptive weather. Even though the northern location of the nation protects Canada from the high level of severe summer convective storms experienced by the United States, destructive thunderstorms and tornadoes do occur, and in some cases with little or no warning. The resulting hail, floods and strong, destructive winds constitute a significant threat to public safety. Canada also experiences major, large-scale storms bringing damaging winds and destructive rains and floods. These winter storms bring snow and mixed precipitation and need to be forecasted days in advance to prepare population centers for adequate response.

As a consequence of the importance of climate, air quality and weather in Canadian society, the research and development activities of the Meteorological Service of Canada (MSC) continue to be vital for the health and safety of the public and for informed policy formulation by the Canadian federal, provincial and local governments.

2.2 State of the Science of the Meteorological Service of Canada

The Panel was impressed with the overall high quality of the science represented by the MSC research and development program.

In some cases the program components are the world leaders. For example, the MSC capability in cloud physics instrumentation and data analysis is better than any other in the world. The numerical dynamic core of the Global Environmental Model (GEM) for numerical weather prediction also represents the leading edge of the science. The Research Data Management and Quality Control System (RDMQ^{TM}) has received worldwide attention and been adopted by other agencies including the World Meteorological Organization's (WMO) World Data Centre for Precipitation Chemistry and the United States Environmental Protection Agency (EPA).

In several areas the MSC research and development program components are world class, representative of the best the global science community has to offer. Notably among these is the Canadian climate modelling capability. The Canadian climate model and the United Kingdom's Hadley Centre climate model were recently used by the United States for input into the national climate impacts assessment. Canadian measurements of greenhouse gases have been shown to be of world class quality and have been used by researchers worldwide to investigate the global carbon cycle and climate change. Additionally, Canadian science has been fundamental in the formulation of international protocols for the long-range transport of persistent organic pollutants and heavy metals.

In several cases the MSC R&D components represent the best available science within Canada. One example is the capabilities within MSC for sophisticated data assimilation methods vital to state-of-the-art numerical weather, air quality, and climate prediction. Many of the laboratory capabilities within air quality research are the best in Canada, as well.

The panel was impressed with both the quality and the productivity of the research personnel of the MSC Research and Development Program. The level of peer-reviewed publications of the scientists was excellent. Many of the individual scientists were recognized both nationally and internationally for their scientific contributions.

Interviewees from international, national and provincial agencies repeatedly stressed the high quality and importance of MSC's contributions. The involvement of MSC staff and research efforts to the WMO's Global Atmospheric Watch (GAW) were particularly highlighted. Contributions include support of the WMO Antarctic Ozone Bulletins, the management of the World Ozone and Ultraviolet Radiation Data Centre, and the vital nature of many of the Canadian environmental measurement activities (such as those at Alert).

2.3 Appropriateness of the Science

Canada's national policy priorities relating to air quality and climate change have driven a considerable part of the overall research and development program of the MSC. Canada's unique role and responsibility in arctic (cold climate) research is recognized globally. Canada is widely viewed as a key steward of the arctic environment.

The Panel concluded that the overall MSC R&D program focus is appropriate, however several individual findings and recommendations in the Sub-Panel reports, which follow, identify areas for improvement.

2.4 Factors Impacting the Research and Development Program's Performance

2.4.1 Resource Pressures

The Program Review of 1994-1998 resulted in a reduction of approximately 35% in the resource levels of the research and development program. The Panel concluded that the reduction in resources did not result in a significant reduction in the scope of the overall program. The consequence was a program that was 'a mile wide and an inch deep', in other words, a program that covers all the original areas but is very limited in terms of the critical mass of people, facilities, and financial resources required to remain a strong, vibrant part of the research community.

Among the many consequences of this situation are poor demographics in the research career field — the age distribution of the research scientists is quite top-heavy with few hires of younger scientists in recent years, a lack of effective career and succession planning, and an increasing reliance on soft money to sustain the infrastructure.

The Panel is encouraged by the activities currently underway to increase the hiring of younger scientists. However, the Panel emphasizes the necessity of active succession planning, especially in the critical senior scientist positions and the research managers. The Panel is also concerned that the increased reliance on soft money may diffuse the focus of the MSC R&D program from the Environment Canada (EC) mandate.

2.4.2 Transfer of "Basic Research" to the University Community

The Canadian government is moving toward a policy of increasing use of the University community to perform basic research in preference to internal governmental research activity. The creation of the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) is a good example of this policy shift.

This action can have a positive impact on MSC because it will tend to expand the science base within the Canadian university structure in areas of importance to the core mission of MSC. In the long term this should have a positive impact on the sciences central to the needs of the MSC.

The short-term implication (3-5 years) of this transition, however, could be negative for MSC. Careful planning will be required to ensure the maintenance of quality science within MSC — an important asset if MSC is to continue to be a "smart buyer" of science from the academic and other non-governmental institutions. Those managing the external research programs of MSC must have expert knowledge in their areas of responsibility. Consequently, the transfer of basic research to the university community does not negate the requirement to maintain a strong scientist cadre within the MSC. A strong scientific cadre of personnel is required to ensure an effective transfer of technologies developed in the academic community to the operational services of MSC.

2.4.3 Environment Canada's Decentralized Organizational Structure

The complexity of the "matrix" management structure of Environment Canada diffuses management focus. The existence of the fully integrated Regional structure, with the reporting lines "stove-piped" to the Deputy Minister, interferes with the functional Assistant Deputy Ministers' ability to coordinate and direct programs consistently across the nation. This can be particularly troublesome for a line-based, service organization such as MSC. Good meteorological service depends upon consistent operating principles and quality control methods to ensure an effective and efficient national observing and forecasting system.

Specifically in the area of Regional research and development activities, the Panel noted a mixed level of effort. There were outstanding examples of Regional programs aimed at meeting the specific Regional needs, such as the Pacific 2001 field program in air quality research, the OURANOS program in climate, and the Atlantic Environmental Prediction Initiative in coupled ocean-atmospheric modelling. Although these are good examples of individual Regional research initiatives, it is not clear that there is an effective mechanism to promote coordination of such activities across the Regions and within MSC.

2.4.4 Increased Emphasis on Technology Transfer

There is an increasing awareness within the ranks of the MSC research scientists of the importance of effective technology transfer from the R&D laboratories to the operational arms of MSC. The researcher reward system has recently been adjusted to provide credit for technology transfer activities in addition to the conventional credit for publications of research results. The Panel encourages this emphasis as an essential part of any government R&D activity.

2.5 Impacts and Assessment Activities in Support of the MSC Research and Development Program

The Panel was very favorably impressed with the existence and performance of the Adaptation and Impacts Research Group (AIRG) of MSC's R&D program. The location of the impacts activities with the various university groups permits the leveraging of the broader university community while at the same time furnishes the university researchers a look into the governments policy development process. The study of climate change impacts on the Canadian National Park System is an example of this interaction at its best.

The activities of Science Assessment and Integration Branch (SAIB) of MSC provide another impressive linkage to the national and international policy development process. This Branch played an effective role in bringing science to the policy makers in the area of acid deposition, smog and toxic materials transport. MSC is to be commended for allocating a portion of their scarce resources to these vital activities.

2.6 Recommendations

The majority of the Panel's findings and recommendations are included in the Sub-Panel reports that follow and will not be repeated here. Some overarching recommendations are presented below.

2.6.1 Management Issues

Strategic Plan: A well articulated strategic plan for the science within the MSC (for both the national and regional levels) should be developed and accepted by all levels in the organization. Full participation of regional levels is critical to a successful planning activity. This plan should recognize existing research agendas (e.g. WEP, CE), clearly define the highest science priorities and focus the R&D efforts throughout MSC. This is of particular importance when the resources may be further limited. The planning should be done in conjunction with the MSC-wide strategic plan to mesh with the overall programmed changes in the operational systems and procedures. The close linkage between the scientific based operations and the supporting research will therefore be enhanced.

The Panel noted unevenness through the regional structure for R&D with some Regions having well developed programs, responsive to their regional needs, while others had diffuse efforts that had little coherence with regional or national programs. It is important that any strategic planning within the MSC include both national and regional needs.

Succession Planning: An effective personnel succession plan should be constructed to ensure the development and continuity of qualified research managers for the MSC R&D program. Interviews with a cross section of research personnel indicated that there was little incentive to move into research management. Overwork to meet too many objectives with too few resources, a deficient career development process, and some problems in succession planning are all aspects of a perceived sub-optimal level of leadership in staff management. Management needs to engage in a plan for staff replacement at the research and managerial levels. This is a challenge for MSC senior management — one that must be met to ensure an ongoing, vibrant R&D organization.

Client Interaction: Better interaction with both internal and external clients is needed. The interviews with MSC internal clients (Regional Directors, other senior managers) yielded mixed results with respect to the openness of the communications between the producers and users of the research and development results. Similar results were obtained when interviewing the MSC external clients (other government officials, private sector users). With both types

of clients the panel heard examples of outstanding interaction as well as situations when the communications were essentially nonexistent. The excuse for poor outreach was usually limited resources, but the Panel feels it is necessary to ensure effective communications with the users is a priority effort in any program.

University Collaboration: Continued development of the university collaboration is essential, both in response to the governmental policy shift as well as the practical goal of securing the best possible science for the MSC mission. The Panel recommends the development of joint projects under the CFCAS, base funding, or other mechanisms to address the priority research issues of both the regional and national programs. This should have the long-term impact of adding national capability to meet the needs of weather, air quality, and climate services for the Canadian public.

Ongoing Review: The panel recommends a periodic review of the responses to this report, including evaluations of progress in the various areas highlighted. Such a review could be accomplished by an advisory committee which would provide continuity, or by ad hoc committees targeted to specific areas.

2.6.2 Programmatic Issues

Environmental Monitoring: The Panel noted a continuation of the (mistaken) historic view that monitoring is not science. The status of monitoring activities throughout MSC, particularly in climate and air quality research, should be carefully examined and the criticality of monitoring activities should be well recognized. The Panel is especially concerned about the potential loss of such vital environmental observing sites as Alert and Eureka.

Verification Program: Verification technologies for the various products of the MSC forecasting enterprise were unevenly applied across the Service, resulting in a situation that made it difficult to judge the quality of service and trends in that service. A quality, nationally implemented verification program is necessary to enable management of MSC to identify areas of needed enhancement and to measure the results of alternative approaches to improve meteorological services.

Water Resources: The Panel was surprised to find the lack of a coordinated water resources and flood forecasting program at the national level. The national priority placed on water quality and the criticality of water to many aspects of the nation's economy, would seem to demand a quality program to provide information on water quantity. MSC seems poised to be able to provide such a service with the major research in quantitative precipitation under the Canadian Weather Research Program (CWRP), the completion of the national radar network and the planned improvements in mesoscale forecasting.

Unified Modelling: The Climate Sub-Panel recommended that the management of the climate R&D activity explore using more unified modelling approaches such as being variously employed at UKMO, NCAR, and GFDL. Such unified modelling approaches are already proving to be more efficient in terms of both personnel and financial resources than independent model developments for global and regional studies. Subsequent to the deliberations of the Climate Sub-Panel, the Meteorology Sub-Panel examined the science of the Global Environmental Model (GEM) for numerical weather prediction (NWP). The Sub-Panel concluded that the GEM dynamical core represents the best in the world. As a result of these conclusions, the Panel would strongly recommend carrying out a feasibility study of using the GEM dynamic framework for both numerical weather prediction and climate models and using the considerable expertise of the climate modellers within MSC as the source of the physical parameterizations necessary for both efforts. The Panel believes that by taking the best of both groups, faster progress can be made in both weather and climate forecasting.

2.7 Concluding Remarks

The MSC R&D program is fundamentally sound and is responsive to the needs of Environment Canada and the Canadian citizens. The Review Panel was impressed with the professionalism and dedication of the scientists and managers in the program. The recommendations in this report are presented in the spirit of improving an already excellent program.

The Panel thanks all MSC personnel who participated in this review. Particular thanks go to Adam Fenech and Kristina Brown of MSC and to Stu McNair of CSM Consulting for their logistics support of the entire review. They made our task easy.

Elbert W (Joe) Friday, Jr.
Chair

3. SUB-PANEL FINDINGS

3.1 Climate Research

The Review Panel convened at the Meteorological Service of Canada (MSC) Headquarters in Toronto from October 22 - 24, 2001. The lists of Panel members and their contacts appear as appendices to this report.

3.1.1 Program Management

General: Despite its small size relative to its climate-oriented mission and operational commitments, the Climate Research Branch (CRB) is remarkably effective, both nationally and internationally. ***The Panel finds that climate research in MSC is appropriately goal oriented and properly aligned with Canada's specific climate-interests and policy-guidance needs.*** The MSC's climate research program is committed to a broad and deep climate research agenda on selective issues of high Canadian priority.

The successful effort of the Science Assessment and Integration Branch (SAIB) to create an effective climate information outreach to a wide variety of Canadian clients is an important achievement, rarely duplicated in other countries.

MSC's active climate research collaborations with the Canadian university community are widespread and fruitful, however ***the Panel recommends that the level of CRB's international modelling research collaborations be increased.*** Such collaborations would likely strengthen CRB's total productivity.

While the geographically distributed nature of CRB is clearly an obstacle to effective collaboration in many instances, in general it appears to work remarkably well.

Financial Resources: CRB have been efficient stewards of their surprisingly limited budget resources. Indeed, the Review Panel sees them as being the most understaffed, relative to breadth and depth of their mission, of any of their major international peer institutions. ***The Panel finds that additional resources are required to reduce the vulnerability of CRB, to continue to carry out the present mandate to the highest standards, and to take on new work of high priority to national needs. In spite of the need for additional funding, the Panel recommends caution in allowing further increases in dependence upon "soft money" as this could dilute the focus and effectiveness of MSC's climate research mission.*** The Panel is convinced that even a doubling of the CRB research budget over, say, a five-year period would still be regarded internationally as a comparatively low commitment to its stated interests in climate understanding and services.

The practical goals of MSC's climate research program must be supported by a level of scientific underpinning sufficient to ensure optimal support for Canada's broad array of climate services. It is widely recognized that operations-oriented weather and climate organizations need to support the right level of basic science to meet their mission goals. Unfortunately, when budget stresses become serious, the required basic research support often experiences serious declines. This appears to have happened to CRB over the past decade.

CRB merits strong commendation for its service commitments to major international climate programs, particularly those of International Panel on Climate Change (IPCC) and World Meteorological Organization (WMO). However, it must be recognized that, while collaborations and participation in international climate programs are fundamental to Canada's climate interests, they require substantial staff "overhead" that must be specifically supported. If such services are not directly supported, they levy an implicit "tax" on key research organizations, such as CRB.

Human Resources: The staffing of CRB is remarkably thin relative to their current effectiveness and stature within Canada's goal-oriented climate research and services program. The quality of the leading scientists, some of whom are internationally recognized climate researchers and leaders, is impressively high. However, there is an urgent need to prepare for the replacement of soon-to-retire, critically important senior scientists and managers, through targeted recruitment and development of future leaders. There are many individuals absolutely critical to the program who have no qualified persons available to replace them. Some of these individuals are close to retirement, most notably in Canadian Centre for Climate Modelling and Analysis (CCCma) modelling staff. ***The Panel is also concerned about MSC's possible inability to stop the evident "brain drain" of talented Canadian climate scientists to the U.S. The Panel recommends a careful review of research expertise required for MSC to continue to deliver on its R&D mandate. This review should produce a transition and succession plan to address potentially critical gaps.***

The Canadian university scientists who collaborate with CRB scientists are highly laudatory of CRB's research talents,

conscientious services, and devotion to the many collaborations. The Panel strongly endorses the statement by a prominent Canadian professor that "the CCCma modelling effort is a jewel in the crown of Canada's government research."

3.1.2 Specific R&D

Cold Climate Research: Climate research has revealed that high Canadian latitudes are expected to warm more and faster than other regions. Research suggests that such warming is likely to produce serious ecosystem disruptions and extinctions of vulnerable species. Canada has an opportunity to be a world leader in understanding the stresses on this treasured ecosystem. The current progress toward the long-term goal of a strong Canadian program in regional impacts of climate change is an important achievement. However, the Panel finds that an insufficient level of attention appears to be given to ecosystem monitoring of northern Canada, a key "early-warning" area of anticipated serious impacts of climate warming.

The Panel was pleased to learn of the high level of maturity of the Boreal Ecosystem Research and Monitoring Sites (BERMS) and Boreal Ecosystem-Atmosphere Study (BOREAS) ecosystem and CO_2 exchange research studies — an achievement of genuine value to Canada.

The Canadian Land Surface Scheme (CLASS) land-surface sub model appears to be an important achievement in support of Canada's regional climate goals. The development and evaluation of CLASS appears to be well coordinated with the BERMS and the preceding BOREAS studies.

Measurement and Data Management: CRB has demonstrated important leadership in the ground-based evaluation and improvement of satellite remote sensing measurements of Canadian snow cover. For example, operational snow water equivalent products from SSM/I enjoy widespread use by the agriculture and water resource communities.

The Panel recommends continued effort to rescue, rehabilitate, and reveal the inherent information contained in Canada's ground-based climate data sets. Efforts to rehabilitate precipitation data sets have been especially effective and they have set an example for the international community.

The Panel recognizes the quality and merit of the Mackenzie GEWEX Study (MAGS) Program and commends the decision to expand the climate monitoring network across northern Canada to the Global Climate Observing System (GCOS) recommended global density of one station per 500-kilometre square box. However, the Panel expresses concern about the vulnerability of critical long-term observing sites, e.g., Alert, Eureka.

Carbon Cycle: The Panel, while noting several research projects on commendable aspects of the carbon cycle, could not detect an overall integration strategy. ***The Panel recommends that such a strategy be developed and implemented.***

3.1.3 Interaction of R&D with Other MSC and EC Activities

The Panel was briefed on the organizational structure of EC, MSC and various other agencies of relevance to the MSC climate research program. However, the brief duration of the review was inadequate for the panel to come to any conclusions about the effectiveness of the multi-dimensional management matrix in facilitating effective working relationships between the Regional and National offices of EC.

3.2 Air Quality Research

The Review Panel convened at the Meteorological Service of Canada (MSC) Headquarters in Toronto from October 30 to November 1, 2001. The lists of Panel members and their contacts appear as appendices to this report.

3.2.1 Program Management

General: MSC is to be congratulated for calling this review, and for preparing high quality presentations and the large amount of supporting documentation. Given that the Panel has had only a few days' exposure to a very complex organization, the Panel appreciates that MSC management may well find that some recommendations require balancing with other considerations.

The Panel notes that the preceding review was conducted in 1991. ***The Panel recommends a shorter review cycle of approximately 5 years to assure that adequate attention to change is being addressed. Actions following from the current review should be addressed explicitly by MSC in material prepared for the next review.***

The Panel notes the impressive compilation of MSC's air quality research program accomplishments. ***The Panel recommends that MSC R&D accomplishments be described in terms of impacts on the actions of others (outcomes) rather than program products (outputs).***

The Panel notes the broad range of MSC air quality R&D activities, and recognizes the need to maintain expertise in these areas. However, the Panel also recognizes the strategic need to anticipate emerging issues and to initiate new activities in preparation for them. ***The Panel recommends adoption of a planning process involving both bench scientists and management that would assist in identifying and prioritizing new initiatives. A mechanism for presenting recommendations for consideration at higher levels of management would be an important part of the process.***

The Panel noted that there is evidence that management is indeed responsive to perceived priority changes, especially if there are no significant financial consequences. Otherwise, responses are sometimes at best sluggish. The Panel notes that there seem to be issues with:

- capital items renewal;
- employment of staff who would work on externally funded projects; and
- lack of support for staff seeking external funds where the needs for financial reporting are high.

The Panel is pleased to note a new level of interaction between CRB and MRB — a symptom of the rather artificial demarcation between these Branches. Priority setting and reporting needs to take place across the Branches. Separation for line management purposes may well be the best approach, but effective research delivery requires strong interaction. CRB would appear to have a major stake in CO_2 and other greenhouse gas monitoring programs of AQRB. This does not seem to be recognized even though the most prospective science may well lie in these '*cracks*'. ***The Panel recommends that interaction between CRB and AQRB be strengthened and that the area of air chemistry-climate-ecosystems coupling be considered as a most prospective emerging area of investigation.***

The Director of the Scientific Assessment and Impacts Branch (SAIB) impressed the Panel by her evidence of consequences from the important assessments of the state of knowledge that the Branch has prepared, generally with strong participation from AQRB scientists. ***The Panel recommends that SAIB take advantage of its excellent position to proactively represent the contributions that ACSD Branches (AQRB in particular) are making to Canada's contribution to national and international science and policy development.***

As evidenced from some interviewee responses, ***the Panel recommends that MSC (and therefore ACSD and AQRB) gives more attention to providing information to the public on the state of Canada's air environment and the impacts that Canadian scientists are making.***

Human Resources: The Panel considered the numerical balance between research scientists and support staff. At first sight, the balance within Air Quality Research Branch (AQRB) of 27% to 63% respectively, in the 138 staff employed, seems to be a generous support level. However, the big network monitoring activities involve approximately 48 support staff, and the Panel discovered that there are several support staff who are actually acting as research scientists (initiating research) — perhaps up to 10 such staff. Even though there appear to be several reasons for a high percentage of support staff in AQRB, ***the Panel finds that the ratio appears large by comparison with international experience.***

While employing graduates as support staff (PC classification) is a means of testing the potential of future science leaders in MSC, ***the Panel recommends a real mechanism for them to be able to make the move to research scientist (RES classification), and a regular assessment of suitability for that move.***

Breadth of expertise was repeatedly cited in interviews as contributing to the high level of enthusiasm with which ASCD scientists approached their research and with which external scientists viewed their collaborators. Nevertheless, there seems to be a gulf between the priorities defined at the WEP and CE tables and ratified at the level of ACSD, and the pressures experienced by working scientists. Overwork to meet too many objectives with too few resources, a deficient career development process, and some problems in succession planning are all aspects of a perceived sub-optimal level of leadership in staff management. The Panel was told that there is no regular staff objective-setting and appraisal process. One used to exist but this has fallen away, probably related to the major funding cuts in the mid 1990s.

The Panel recommends that management restores an appropriate and effective objective-setting and performance appraisal system as part of an overall framework for staff management and development. The Panel also recommends that management increases efforts to develop a plan for staff replacement at the research (RES) and managerial (REM) levels.

Cold Climate Research: The Panel was repeatedly impressed by Canada's support for programs at high latitude stations. These are clearly unique international contributions. The work on polar sunrise, mercury transport and deposition, ozone depletion and UV are great examples where observations have identified new science.

Canada's unique role and responsibility in arctic research is recognized globally. Canada is widely seen to be a key steward of the arctic environment. ***The Panel recommends that MSC couches and interprets its unique international atmospheric science role in terms of cold climate aspects of air quality as broadly defined by MSC.***

Canada's international leadership in arctic research should be protected. ***The Panel recommends that arctic programs be high among the priorities of MSC R&D. MSC would appear to have good reason to request specific funding for this work.***

Priority Setting: The Panel is concerned that AQRB may be overextended and have insufficient depth in some priority areas. ***The Panel recommends that a refinement of research objectives at the Branch and Division levels be undertaken.***

The panel recommends that a 10 year strategic research implementation plan be developed for MSC. The plan would address WEP and CE research priorities and would provide clear direction as to which scientific issues would receive highest priority for funding. The object would be to maintain depth of program. Other objectives would also be supported, but clearly they would be at a reduced level: one that ensures a familiarity with the area so that advice can be provided as necessary.The plan would be developed with participation of scientific staff and consider:

- scientific strengths within the MSC;
- scientific strengths in other agencies and organizations;
- unique opportunities and contributions that could be made to regional, national, and international issues; and
- the potential interface with current and anticipated policy needs.

3.2.2 Specific R&D

Monitoring and Data Management: Results from the stakeholder survey undertaken for this review showed that past efforts to charge for data supply have been counter-productive, creating animosity to MSC. ***The Panel recommends that efforts to restore and improve reporting of air quality monitoring data on the World Wide Web continue.*** This should go a long way to improving engagement with the wide range of university and Regional stakeholders in MSC.

The Panel examined the issue of remote sensing, particularly from Eureka. The Panel notes the unique assets available to MSC (such as the Eureka observatory) that contribute to the international efforts aimed at elucidating the coupling between stratospheric ozone depletion/recovery and climate change. As the Arctic region is thought to be particularly vulnerable to continued erosion of the ozone layer over the next 1-2 decades, such measurements are a clear Canadian priority. Links between stratospheric ozone recovery and climate change are seen by the Panel as particularly important research areas for which AQRB is uniquely placed to contribute. Additionally, the Eureka observations serve as an important calibration source for providing a 'ground-truth' of the environmental satellite observations. ***The Panel recommends that cutbacks to the remote sensing program should be re-examined in light of the strong contribution to understanding polar chemistry that is uniquely provided by Eureka data sets.*** Continuation of such measurements contributes to the Network for the Detection of Stratospheric Change (NDSC), and is strongly encouraged.

The Panel notes a continuation of the historic view that monitoring is not "science". In practice, today's environmental concerns require attention to a variety of chemical species and physical processes, many as yet ill-defined and subject to advances in techniques and understanding. The Panel agrees with the concept that routinely operating network operations should be protected from the vagaries of support for research programs. Systematic monitoring is seen to be an essential component of any national environmental program.

The Panel finds that MSC's approach of a CORE network is correct. These CORE stations serve as centres for developing new methodologies for both measurement and data interpretation. They are quite distinct from what could be regarded as "systematic monitoring".

The Panel examined whether monitoring, regarded as routine, can be transferred to other agencies. This can certainly work if the monitoring is not too complex, does not require exceptionally high accuracy of results, and can be separated from research programs that are able to work without close feedback to monitoring work. Indeed, maintenance and capital replacement can work better in an agency that is able to resource and plan long term routine monitoring work. ***The Panel recommends that ACSD assess monitoring activities that are part of Branch research projects. Those that continue to involve a substantial scientific contribution to meet the required quality and development should remain within ACSD. Those that do not, and can be described as systematic monitoring, should be transferred to Atmospheric Monitoring and Water***

Survey Directorate (AMWSD). The panel finds that the CORE network should not be considered for transfer out of its parent research home.

The Panel notes that the important acid deposition monitoring network, Canadian Air and Precipitation Monitoring Network (CAPMoN), is highly labour intensive. Like many similar networks around the world, the operation of CAPMoN is very conservative and this needs to change as demands for resources continue to be high and subject to ongoing reassessment. The Panel supports the approach of coupling CAPMoN with the CORE network, where appropriate. ***The Panel recommends that AQRB investigate techniques for automated multiple sampling of acid rain, principally to reduce the cost of running the network.*** This investigation should include experiences in other countries, including Japan. The recommendation to consider automation is a strong reason for keeping CAPMoN as a research monitoring network ***— the Panel finds that it is not yet time to regard this activity as a candidate for systematic routine monitoring.***

The Panel notes that Ozone Depleting Substances (ODSs) seem only to be monitored at the Alert monitoring station, and do not appear to feature in significant research projects. ***The Panel recommends increased monitoring of ODSs as a necessary activity of AQRB for surveillance of national and global commitments to the Montreal Protocol.*** Best value is obtained if the results are integrated into a Canadian surveillance modelling program.

Health Impacts: Air quality and health features strongly in the EC Clean Environment Agenda, but the MSC implementation is minimal: 1 lead and 2 support scientists, and these rely greatly on external funds. Canada's supersite in Toronto appears to be exemplary but research benefits are starved from lack of resources. ***The Panel recommends that the priority of air quality-health issues within the MSC R&D program be reassessed in view of the high national priority for this issue and that funding and mandate issues be resolved with Health Canada, as indicated in Section 3.2.3. of this report.***

Modelling: The Panel examined air quality modelling activities and their future in the MSC. It is clear that this is a very broad activity, with strong past accomplishments. Air pollution forecasts of ozone and particles are evidently a priority that can only be met by MSC, especially as spatial resolution is refined to 5 km and 1 km. The demarkation that sees weather forecasting and climate modelling undertaken in other parts of MSC appears to the Panel to be a weakness that stronger interaction could alleviate. ***The Panel finds that AQRB is the natural home for air quality model development in MSC. However, the Panel recommends closer interaction with meteorological model developers.***

Noting the need for MSC to be familiar with MODELS-3 and other international models, and for some of them to be used for some applications, ***the Panel recommends that AQRB continue the development of the AURAMS integrated model.*** This approach offers, amongst other things, an expression of the leading edge national and international science important to Canada's air quality concerns.

The Panel finds that modelling priorities in AQRB should be:

- ***ozone and fine particles down to local scales;***
- ***acid deposition and eutrophication;***
- ***heavy metals and Persistent Organic Pollutants (POPs); and***
- ***greenhouse gases (inverse modelling).***

The Panel recommends that a feasibility test be conducted to evaluate the potential benefits of chemical data assimilation for surface air quality prediction before committing significant resources to this activity.

Inverse Modelling: The Panel was told that AQRB has not had much impact on Canadian policy-makers regarding greenhouse gases; the greatest outcomes have been in acid deposition, Hazardous Air Pollutants (HAPs) and Particulate Matter (PM). This seems to be in part because Canada has left it to others to obtain the full benefit of the high quality greenhouse gases monitoring data that AQRB has provided.

The Panel notes that a continuing balanced program of ground-based remote sensing and satellite measurements is desirable to address and understand complex atmospheric chemistry/climate issues. In particular, ground-based measurements provide a unique capability for validating satellite measurements, for ensuring long-term continuity of trends quality data sets, and for conducting complementary science investigations. ***The Panel finds that MSC could achieve greater benefits from the commitments to monitoring by actively employing the outputs from these measurement systems in interpretive modelling capabilities. The Panel recommends that an inverse modelling activity be initiated within the Modelling & Integration Division, and be strongly coupled to the greenhouse gas measurement activities of the Measurements and Analysis Division.*** The success of this modelling will require incorporation of other data sets internationally (e.g. NOAA/CMDL, NASA/AGAGE, etc.) and, if necessary, should be prioritized above existing data assimilation activities. This activity is important for providing

guidance as to the veracity of claims of national greenhouse emissions performance, a need that currently seems to not be recognized by Environmental Protection Service (EPS).

3.2.3 Interaction of R&D with Other MSC, EC and External Activities

Modelling: The Panel notes that the modelling area in AQRB has been the focus for many demands from within MSC, by EPS, and by provinces and the Regions. Not all of these demands have been met in a timely manner. The Branch has on occasion not strongly risen to meet the urgency that policy and development clients have themselves had. The Panel notes that AQRB seems comfortable with the planned Canadian Meteorological Centre (CMC) activities in applications (scenarios and forecasts), thereby allowing AQRB to focus on the development of a unified modelling system and to establish priorities on how that development should proceed. ***The Panel recommends that model development activities within AQRB should be focused on research support and that applications activities in support of forecasting and policy applications should be transferred to CMC.***

The Panel noted that Ontario Ministry of Environment (OME) is planning to model acid deposition using Generic Reaction Set (GRS) chemistry. ***The Panel recommends that AQRB compare A Unified Regional Air Quality Modelling System (AURAMS) results for modelled deposition fields with those of OME.***

Policy Support: The Panel recognizes the different challenges EPS and MSC in the areas of air quality and atmospheric deposition, and notes that the two organizations share needs for the same science. There is clearly a need to examine the way in which the two organizations interact, so as to accelerate developments in air quality and deposition model development, for the unique national situations of Canada. ***The Panel recommends establishment of a forum for periodically communicating EPS needs for MSC science and for MSC to communicate their capability (existing or planned) to deliver such*** — following the Canadian Government's Building Excellence in Science and Technology (BEST) principles of Alignment, Linkages and Excellence, and its Framework for Science & Technology Advice. ***To this end, the Panel recommends a review of air quality and deposition activities under the jurisdiction of the Clean Environment Table. This would serve as a mechanism to draw experts together, and to generate guidance for decision makers sitting at the Clean Environment Table.***

Health Impacts: Discussions concerning the relevance of air quality to human health concerns revealed a problem common to many agencies, world-wide — the matter of whose budget should support work in which a topic relates to one agency's mission, yet critical expertise lies in another. A current consequence is that requests of Health Canada for MSC involvement in exposure assessments appear not to be being met. ***The Panel recommends that high-level discussions take place to address the health funding issue and to develop some equitable solutions.*** It is clear that, for the effort available, AQRB is contributing strongly to national programs on health effects of air pollutants. This high-priority national concern deserves an increased level of attention, but where and how this can be accomplished requires inter-agency deliberation.

International Programs: The scientific contribution from AQRB staff to air quality policy development extends well beyond the North American region. Within the framework of the United Nations Economic Commission for Europe (UNECE), Canadian participation has been fundamental to formulation of international protocols on the Long Range Transport of Persistent Organic Pollutants and Heavy Metals. AQRB provided the scientific leadership and substantiation that brought the member states together and provided direction concerning monitoring methods and emissions inventories.

Interviewees from international, national and provincial agencies repeatedly stressed the high quality and importance of MSC and AQRB contributions. The involvement of AQRB staff and research efforts to the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) were particularly highlighted. Contributions include support of the WMO Antarctic Ozone Bulletins, the management of the World Ozone and Ultraviolet Radiation Data Centre, the maintenance of the world standard for Brewer calibrations, the staffing of GAW committees (e.g., the Scientific Advisory Groups and the WMO Executive Council Panel), and direct support and involvement in measurement activities at GAW stations (such as Alert) and at stations in contributing networks (such as Eureka in the Network for the Detection of Stratospheric Change).

3.3 Meteorology Research

The Review Panel convened at the Canadian Meteorological Centre (CMC) in Montreal on November 27-29, 2001. The lists of Panel members and their contacts appear as appendices to this report.

3.3.1 Program Management

General: The Panel was provided with good background material and excellent presentations and opportunities to interview staff at all levels. The Panel noted the Terms of Reference, set consistently with the Federal Science and Technology (S&T) Strategy. It also noted the core terms of reference with a focus on the research and development (R&D) area. The review seeks to specifically address the latter issues but also engages some issues from the wider S&T Strategy where it felt wider improvements in organizational effectiveness were possible. The report begins with the specific R&D issues noted and follows with wider interaction issues.

Overall Quality: The Panel was most impressed by the quality and productivity of the R&D area. It judged all activities to be at an excellent standard and undertaken with due regard to, and often linked to, international activities. It further noted that a number of key activities were of world leading standard and noted that these areas of special strength were strategic in relation to staff skills and Environment Canada (EC) needs.

Limited Staff Resources: The Panel was very concerned that the number of staff is too few to carry out the R&D mission of MSC and to allow effective succession planning. The Panel notes that the recent dip in the weather prediction score relative to other Centres, though now largely resolved, arose as resources limited the ability to undertake necessary work on data assimilation and separate work on new satellite data at the same time. Staff resources are clearly at a critical level. The Panel notes further that as is common in many educational and research institutions in North America, the professional staff at MSC is aging as reductions in resources have slowed or eliminated hiring of younger people in the past decade. As a result, some of the programs and activities of MSC have demographic gaps that can lead to serious shortfalls in scientific expertise, experience and leadership in the near future. ***The Panel recommends that MSC address this increasing imbalance beginning immediately and continuing for a number of years until a healthy demographic balance is restored.*** Resources simply must be found to permit the hiring of young people. MSC should provide appropriate leadership and management training programs for middle-career staff that will become the leaders of MSC during the next decade. MSC should consider use of "early retirement" incentives to create additional resources and openings for young people.

Importance of International Collaboration and Communication: Weather forecast and climate models, observational and data assimilation systems, and in fact the entire forecast production process are becoming more and more complex. At the same time, the resources in many countries for weather and climate research and operations are decreasing. These two factors mean that it is more important than ever for research and operational organizations to communicate and collaborate. More rapid progress of all national weather services can occur through the sharing of ideas, best practices and in some cases software. The collaboration of MSC research scientists (e.g. Recherche en Prévision Numérique (RPN) and Data Assimilation Division) with similar groups in Europe and the United States appears to be healthy and mutually beneficial to MSC and to the foreign institutions. These collaborations need to be maintained and could be extended and enhanced through a variety of mechanisms, including joint projects, short and long-term visits, exchange of software where appropriate, etc. Improved collaborations between CMC and other similar operational institutions such as National Centers for Environmental Prediction (NCEP) are a good opportunity for this. ***The Panel recommends that MSC assess the possibilities for increased collaborations with similar institutions internationally and support new or enhanced collaborations as appropriate.***

Need for Strategic Planning: The Panel has already noted the high quality of the MSC programs. However, the Panel did not sense that the excellent individual group efforts fit into a larger strategic framework which links with matching plans involving users. ***The Panel recommends that the MSC create such an integrating framework by developing a strategic plan that looks ahead over the next 5-10 years.*** This plan should consider how advances in observational and computer technologies, analysis and data assimilation methods, computer science and information technologies and physical understanding create opportunities for improved or new meteorological and climate products of use to society. It should consider human and financial resource needs and appropriate changes to management structures. The planning process, which is often as important as the final plan itself, should involve the scientific, engineering and administrative staff and consider input from a variety of clients and stakeholders.

3.3.2 Specific R&D

Global Numerical Weather Prediction (NWP) Effort: Given the Panel's concern over resources it addressed the question of how essential is it for EC to maintain an independent NWP capability. ***The Panel concludes that it is essential for the following reasons:***

- Global NWP models are an essential part of the total forecast process. The preparation of forecast and warning products is not considered viable without end-to-end

control of the overall process. This is even more crucial with the mostly automated production chain, which resulted from the budget and staff reductions of past years. Use of alternative global NWP models from other centers can lead to serious and unforeseen errors when the systems change and do not match. Equally a regional model needs consistent boundary conditions from a compatible model to avoid boundary and "spin up" effects, so a regional model alone is not sound policy.

- Canada's high latitude and large size mean that a specific focus on issues of the model concerning freezing rain, ice and snow and Canada's land surfaces is vital and not available from other leading Centres.
- More broadly, Canada's economy and well-being are much influenced by weather and climate and a strong national weather and climate program is vital for Canada's welfare. There is a more general issue that a country of Canada's stature and wherewithal would be expected to share international work in this area with other developed countries. Of special significance is the strong need by Canada for climate prediction. By all indications, Canada and Russia are the two nations that will be the most affected by climate change.The science of climate change is not completely understood, especially the regional impacts and appropriate mitigation and adaptation strategies. The Panel concludes that Canada must maintain a substantial effort in modelling and understanding climate change and its impacts. The need as noted below is best met by the linking of NWP and climate models to mutual benefit.

Common Infrastructure for NWP and Climate Models: The Panel recognizes the outstanding advances being made in the Global Environmental Mesoscale (GEM) NWP model and the world leading quality of the dynamical core of the model. ***The Panel recognizes the resource limitations of MSC Atmospheric and Climate Science Directorate (ACSD) and recommends adoption of a common model infrastructure for the Canadian NWP and climate models.*** This could be accomplished by using the GEM dynamical core for the climate model and in turn using some or all of the physics modules and other parameterizations developed for the climate model (after sufficient testing) for GEM.

In relation to the preceding recommendation the cloud physics lead should be retained in its present location. The Panel noted that the cloud physics team, which is the largest physical process group, is both a very much-needed priority for the needs of Canada and is further a world leading group with outstanding productivity and quality of work. ***The Panel recommends that this group and its focus be well supported.***

By moving to a common model infrastructure for all scales (global and meso-scale NWP and climate models) MSC can take advantage of the inherent efficiencies of the single computer codes, and at the same time use its limited staff resources to best effect.

Nowcasting Using a Mix of Observations: The Panel recommends that more attention be given to nowcasting techniques using a mix of radar data, satellite data and short period regional NWP. This area of work should enable, in due course, further automation of service delivery consistent with the overall MSC strategy. Here, as in other areas, collaboration with universities and other national weather services, where much expertise already resides, would aid progress in this field of activity.

Flood Forecasting: The Panel was surprised that the operational links between both precipitation estimates in weather forecast model predictions and radar data, and the application of real time flood and flood control response seemed absent. ***It recommends that improved links with MSC should be established in this area in order to better meet Canadian needs.***

In the broader context of flood forecasting the Panel did, however, note the very successful link between MSC and the Region for storm surge forecasting on the east coast.

Variational Data Assimilation: The work on variational assimilation (3D and 4D) is another area of leading world standards. Now that most of the technical developments for implementing 4D-var have been completed, major improvements in the forecasts should follow soon. Some attention should now be paid in the improvement of the assimilation of water in its three phases, which requires close relationships with the physical parameterization team. ***The Panel recommends that the work already initiated on the operational use of the existing and soon to come satellite observations should be pursued and even amplified which requires resources for the management of the observational data flow.***

The research on Ensemble Kalman Filter (EKF) is very innovative and of world-class level.The Panel felt that the schedule for phasing out the Optimal Interpolation (OI) currently used in the ensemble prediction system is probably too optimistic. Some efforts could also be devoted to the use of the EKF to improve the "J_b terms" of variational assimilation.

The Panel draws attention to the issue and benefits involved in achieving common software "scripts" for the running of NWP models in MSC and the CMC and the further need for them to interact and respond to the recommended end user

verification of Regional output. Both these points are raised below in the context of interactions outside the MSC area.

3.3.3 Interaction of R&D with Other MSC and EC Activities

Record of Forecast Skill: It is important to keep long-term records of the accuracy of forecasts in order to evaluate progress over time and the impacts of various changes in the entire forecast process, including changes in observations, analysis, data assimilation, models and subjective interpretation of the observations and objective model output. While objective measures of accuracy and skill of the operational NWP model forecasts have been calculated, analyzed and reported for many years, no similar set of measures seems to exist for the public forecasts and warnings issued by the Regions. In some cases, limited statistics do exist, but they are not used extensively or reported publicly. ***The Panel supports the plans to develop, monitor and report standard objective measures of forecasts and warnings in the Regions.*** At the same time, it is important that any forecast verification measures that have been calculated over the years in the Regions should be continued for long-term evaluation purposes. Given the automation strategy it is vital that such verification is seen as a key responsibility of Regional science staff and that the methods are totally consistent between forecast offices.

Communication and Collaboration within Canada: The Panel notes that communication and interactions between the different Regions and CMC need to be improved. The problem is caused by a number of factors including the diffuse management structure, lack of resources in the CMC and Regions, different Regional problems and priorities, and even such seemingly simple things as lack of uniformity in workstations. ***The Panel recommends that MSC assess the present level of internal communication/collaboration and develop mechanisms to increase the interactions among the Regions and the CMC and develop a greater sense of shared responsibility and cooperation across all of MSC.*** Mechanisms such as annual workshops, like the smaller upcoming workshop already planned, joint projects, periodic fora to provide feedback to CMC, MRB and the Regions on NWP products and innovations should be explored. The strategic planning process offers an opportunity to foster communication and development of a shared vision.

Importance of Training: Reduction of resources has led to what several people in MSC leadership positions term as "desperate" or "dismal" to describe the training of forecasters. Forecasting is changing faster than ever before and so training is needed more than ever. Yet resource pressures have forced cutback of training programs and opportunities since about 1995. Involvement with the Cooperative Meteorology Education and Training (COMET) program will help a great deal, but forecasters' time is so severely limited they have little chance to do the distance learning exercises, much less attend training classes. ***The Panel supports an increased emphasis on training and continued professional development of forecasters.*** Adequate training requires conscious development of a positive "training culture," including support by national, regional and local management, time allocated to training, promotion and reward system, etc.

Need for More Uniform Forecast Practices: The Panel noted significant variations in forecast preparation practices between Regions and felt that these differences do not effectively provide the needed user feedback community for Scribe and the NWP products. The Panel is impressed with the development of Scribe, probably one of the most advanced systems of its type. ***It recommends that the Regions seek to achieve a more uniform use of Scribe and other products and, consistent with recommendations, further undertake objective verification of these products using a common approach.*** Given the clear MSC strategy towards automation the Panel feels that it is essential that the science staff in the Regions more fully recognize their role to act as well informed customers and ensure standards of services across Canada. With increased confidence in automated products forecaster attention will then be better able to focus on specialized advice and severe weather events.

Common Script for Research and Operations: The Panel notes that CMC undertook the full development of operational scripts and did not use a common script for model running within MSC. The script command coding for running NWP models involves a great deal of effort and most Centres have, for efficiency, adopted a common script between research and operations. ***The Panel recommends adoption of this approach.*** It requires good cooperation between the two groups and a sharing of work.

3.4 Summary List of Panel Findings

Findings and recommendations from this Independent Peer Review report are listed below. The list is intended for the convenience of the reader and particularly for MSC R&D managers. The findings below should not be read in isolation. Context for each finding can be found in the preceding sections of this report.

3.4.1 Overview

1. A well articulated strategic plan for the science within the MSC (for both the national and regional levels) should be developed and accepted by all levels in the organization. Full participation of regional levels is critical to a successful planning activity.
2. An effective personnel succession plan should be constructed to ensure the development and continuity of qualified research managers for the MSC R&D program.
3. Better interaction with both internal and external clients is needed.
4. Continued development of the university collaboration is essential, both in response to the governmental policy shift as well as the practical goal of securing the best possible science for the MSC mission.
5. The panel recommends a periodic review of the responses to this report, including evaluations of progress in the various areas highlighted.
6. The Panel is especially concerned about the potential loss of such vital environmental observing sites as Alert and Eureka.
7. A quality, nationally implemented verification program is necessary to enable management of MSC to identify areas of needed enhancement and to measure the results of alternative approaches to improve meteorological services.
8. The Panel was surprised to find the lack of a coordinated water resources and flood forecasting program at the national level.
9. The Panel would strongly recommend carrying out a feasibility study of using the GEM dynamic framework for both numerical weather prediction and climate models and using the considerable expertise of the climate modellers within MSC as the source of the physical parameterizations necessary for both efforts.

3.4.2 Climate Research

1. The Panel finds that climate research in MSC is appropriately goal oriented and properly aligned with Canada's specific climate-interests and policy-guidance needs.
2. The Panel recommends that the level of CRB's international modelling research collaborations be increased.
3. The Panel finds that additional resources are required to reduce the vulnerability of CRB, to continue to carry out the present mandate to the highest standards, and to take on new work of high priority to national needs.
4. The Panel recommends caution in allowing further increases in dependence upon "soft money" as this could dilute the focus and effectiveness of MSC's climate research mission.
5. The Panel recommends a careful review of research expertise required for MSC to continue to deliver on its R&D mandate. This review should produce a transition and succession plan to address potentially critical gaps.
6. The Panel finds that an insufficient level of attention appears to be given to ecosystem monitoring of northern Canada, a key "early-warning" area of anticipated serious impacts of climate warming.
7. The Panel recommends continued effort to rescue, rehabilitate, and reveal the inherent information contained in Canada's ground-based climate data sets.
8. The Panel recommends that a strategy [to strengthen integration of various aspects of carbon cycle research] be developed and implemented.

3.4.3 Air Quality Research

1. The Panel recommends a shorter review cycle of approximately 5 years to assure that adequate attention to change is being addressed. Actions following from the current review should be addressed explicitly by MSC in material prepared for the next review.
2. The Panel recommends that MSC R&D accomplishments be described in terms of *impacts on the actions of others* (outcomes) rather than program products (outputs).
3. The Panel recommends adoption of a planning process involving both bench scientists and management that would assist in identifying and prioritizing new initiatives. A mechanism for presenting recommendations for consideration at higher levels of management would be an important part of the process.
4. Panel recommends that interaction between CRB and AQRB be strengthened and that the area of air chemistry-climate-ecosystems coupling be considered as a most prospective emerging area of investigation.
5. The Panel recommends that SAIB take advantage of its excellent position to proactively represent the contributions that ACSD Branches (AQRB in particular) are making to Canada's contribution to national and international science and policy development.
6. The Panel recommends that MSC (and therefore ACSD and AQRB) gives more attention to providing information to the public on the state of Canada's air environment and the impacts that Canadian scientists are making.
7. The Panel finds that the ratio [of support staff to research scientists] appears large by comparison with international experience.

8. The Panel recommends a real mechanism for [graduate support staff] to be able to make the move to research scientist (RES classification), and a regular assessment of suitability for that move.
9. The Panel recommends that management restores an appropriate and effective objective-setting and performance appraisal system as part of an overall framework for staff management and development.
10. The Panel also recommends that management increases efforts to develop a plan for staff replacement at the research (RES) and managerial (REM) levels.
11. The Panel recommends that MSC couches and interprets its unique international atmospheric science role in terms of cold climate aspects of air quality as broadly defined by MSC.
12. The Panel recommends that arctic programs be high among the priorities of MSC R&D. MSC would appear to have good reason to request specific funding for this work.
13. The Panel recommends that a refinement of research objectives at the Branch and Division levels be undertaken.
14. The panel recommends that a 10-year strategic research implementation plan be developed for MSC. The plan would address WEP and CE research priorities and would provide clear direction as to which scientific issues would receive highest priority for funding.
15. The Panel recommends that efforts to restore and improve reporting of air quality monitoring data on the World Wide Web continue.
16. The Panel recommends that cutbacks to the remote sensing program should be re-examined in light of the strong contribution to understanding polar chemistry that is uniquely provided by Eureka data sets.
17. The Panel finds that MSC's approach of a CORE network is correct.
18. The Panel recommends that ACSD assess monitoring activities that are part of Branch research projects. Those that continue to involve a substantial scientific contribution to meet the required quality and development should remain within ACSD. Those that do not, and can be described as systematic monitoring, should be transferred to Atmospheric Monitoring and Water Survey Directorate (AMWSD).
19. The panel finds that the CORE network should not be considered for transfer out of its parent research home.
20. The Panel recommends that AQRB investigate techniques for automated multiple sampling of acid rain, principally to reduce the cost of running the network.
21. The Panel finds that it is not yet time to regard [CAPMoN] as a candidate for systematic routine monitoring.
22. The Panel recommends increased monitoring of ODSs as a necessary activity of AQRB for surveillance of national and global commitments to the Montreal Protocol.
23. The Panel recommends that the priority of air quality-health issues within the MSC R&D program be reassessed in view of the high national priority for this issue and that funding and mandate issues be resolved with Health Canada.
24. The Panel finds that AQRB is the natural home for air quality model development in MSC. However, the Panel recommends closer interaction with meteorological model developers.
25. The Panel recommends that AQRB continue the development of the AURAMS integrated model.
26. The Panel finds that modelling priorities in AQRB should be:
    - ozone and fine particles down to local scales;
    - acid deposition and eutrophication;
    - heavy metals and POPs; and
    - greenhouse gases (inverse modelling).
27. The Panel recommends that a feasibility test be conducted to evaluate the potential benefits of chemical data assimilation for surface air quality prediction before committing significant resources to this activity.
28. The Panel finds that MSC could achieve greater benefits from the commitments to monitoring by actively employing the outputs from these measurement systems in interpretive modelling capabilities. The Panel recommends that an inverse modelling activity be initiated within the Modelling & Integration Division, and be strongly coupled to the greenhouse gas measurement activities of the Measurements and Analysis Division.
29. The Panel recommends that model development activities within AQRB should be focused on research support and that applications activities in support of forecasting and policy applications should be transferred to CMC.
30. The Panel recommends establishment of a forum for periodically communicating EPS needs for MSC science and for MSC to communicate their capability (existing or planned) to deliver such. To this end, the Panel recommends a review of air quality and deposition activities under the jurisdiction of the Clean Environment Table. This would serve as a mechanism to draw experts together, and to generate guidance for decision makers sitting at the Clean Environment Table.

31. The Panel recommends that AQRB compare A Unified Regional Air Quality Modelling System (AURAMS) results for modelled deposition fields with those of OME [using GRS chemistry].

32. The Panel recommends that high-level discussions take place to address the health funding issue and to develop some equitable solutions.

3.4.4 Meteorology Research

1. The Panel recommends that MSC address this increasing imbalance [in the age of professional staff] beginning immediately and continuing for a number of years until a healthy demographic balance is restored.

2. The Panel recommends that MSC assess the possibilities for increased collaborations with similar institutions internationally and support new or enhanced collaborations as appropriate.

3. The Panel recommends that the MSC create an integrating [research] framework by developing a strategic plan that looks ahead over the next 5-10 years. The planning process, which is often as important as the final plan itself, should involve the scientific, engineering and administrative staff and consider input from a variety of clients and stakeholders.

4. The Panel concludes that it is essential [for EC to maintain an independent NWP capability].

5. The Panel recognizes the resource limitations of MSC and ACSD and recommends adoption of a common model infrastructure for the Canadian NWP and climate models.

6. The Panel recommends that [the physical processes] group and its focus be well supported.

7. The Panel recommends that more attention be given to nowcasting techniques using a mix of radar data, satellite data and short period regional NWP.

8. It recommends that improved links with MSC should be established in this area in order to better meet Canadian needs.

9. The Panel recommends that the work already initiated on the operational use of the existing and soon to come satellite observations should be pursued and even amplified which requires resources for the management of the observational data flow.

10. The Panel supports the plans to develop, monitor and report standard objective measures of forecasts and warnings in the Regions

11. The Panel recommends that MSC assess the present level of internal communication/collaboration and develop mechanisms to increase the interactions among the Regions and the CMC and develop a greater sense of shared responsibility and cooperation across all of MSC.

12. The Panel supports an increased emphasis on training and continued professional development of forecasters.

13. The Panel recommends that the Regions seek to achieve a more uniform use of Scribe and other products and, consistent with recommendations, further undertake objective verification of these products using a common approach.

14. The Panel recommends adoption of [a common script for model running within MSC].

APPENDIX A – PANEL MEMBERS

Panel Chair

Elbert W. (Joe) Friday, Jr.

Dr. Friday is currently the Director of the Board on Atmospheric Sciences and Climate at the National Research Council where he has served since July 1998. For the previous year, he served as the Assistant Administrator for Research for the National Oceanic and Atmospheric Administration. From 1988 to 1997, he was Director, National Weather Service, serving during the extensive modernization of the NWS. During this same period, he served as the U.S. Permanent Representative to the World Meteorological Organization. He served as Deputy, NWS from 1981 to 1988.

Dr. Friday completed a 20 year career in the US Air Force, retiring in 1981 as a Colonel. He is a Fellow of the American Meteorology Society, and member of the National Weather Association and Sigma Xi, the Research Society. He has received numerous military awards including the Bronze Star and the Defense Superior Service Medal. He has been awarded the Presidential Rank Award of Meritorious Executive, the Distinguished Graduate Award from the University of Oklahoma (where he received a BS in Engineering Physics in 1961, an MS in Meteorology in 1967 and a PhD in Meteorology in 1969), and the 1993 Federal Executive of the Year Award from the Federal Executive Institute Alumni Association. He received the 1997 Cleveland Abbe Award for Outstanding Service from the American Meteorological Society.

Climate Research Sub-Panel

Chair: Jerry D. Mahlman

Dr. Mahlman is currently a Senior Research Fellow at the National Center for Atmospheric Research in Boulder, Colorado and Lecturer with the rank of Professor in Atmospheric and Oceanic Sciences Program at Princeton University in Princeton, New Jersey. He was the Director of the Geophysical Fluid Dynamic Laboratory of the National Oceanic and Atmospheric Administration in Princeton, New Jersey from 1984 to 2000.

Much of Dr. Mahlman's research career has been directed toward understanding the behavior of the stratosphere and the troposphere. This has involved extensive mathematical modelling and diagnosis of the interactive chemical, radiative, dynamical, and transport aspects of the atmosphere, as well as their implications for climate and chemical change. Over the past decade, he has played a central role in the interpretation of human-caused climate change to policy makers and affected communities. He has received many distinguished awards including the American Meteorological Society's highest honor, its Carl-Gustaf Rossby Research Medal, the Presidential Distinguished Rank Award, Fellow of the American Geophysical Union, and the U.S. Department of Commerce Gold Medal.

David Griggs

Dr. Griggs was Head of the Intergovernmental Panel on Climate Change (IPCC) Working Group I (WGI), Technical Support Unit from 1996-2000. In that position he was an editor of several Technical Papers, the IPCC Special Report on Aviation and the Global Atmosphere and the IPCC WGI Third Assessment Report. He was appointed as Director of Climate Research in the Met Office in April 2001, with responsibilities which include directing and managing the Met Office's climate research and atmospheric dispersion activities, acting as Director of the Met Office, Hadley Centre for Climate Prediction and Research, advising on policy and strategy relating to the provision of advice to Government and the public on issues relating to climate change and external representation of the Met Office on climate related matters.

Dr. Griggs was awarded the World Meteorological Organization's Vilho Vaisala award in 1992.

Mark C. Serreze

Dr. Serreze received his PhD in 1989. Since that time, he has been employed as a research scientist at the University of Colorado, Boulder, CO. He has varied research interests, but has focused mainly on problems in northern high latitudes. Recent work includes assessments of high-latitude hydroclimatology, surface energy budgets, synoptic variability and climate change. He has also been actively involved in assessing the quality of atmospheric reanalyses in northern high latitudes. Dr. Serreze has collaborated both formally and informally with Canadian scientists (government and university) in a variety of research projects. These collaborations have included several seasons of field work in the Canadian high Arctic.

Air Quality Research Sub-Panel

Chair – Peter Manins

Dr. Manins is Leader of the Air Pollution Program in the Atmospheric Research Division of CSIRO (Common wealth Scientific and Industrial Research Organization), Australia. He is an expert on air pollution meteorology and modelling.

Dr. Manins has over 200 publications in refereed journals, conference presentations and consultancy reports on meteorological and air pollution topics. He is a Fellow, Australian Academy of Technological Sciences and Engineering; Public Service Medallist; Certified Consulting Meteorologist; and Qualified Environmental Professional.

Richard (Dick) Derwent

Dr. Derwent is currently an individual merit chief research scientist in the Climate Research Division of the Meteorological Office in the United Kingdom. He has spent his research career building models of acid rain, photochemical ozone formation and the global build-up of the greenhouse gases, including methane and ozone.

Dr. Derwent has contributed to the publication of over 300 papers, reports and other publications on this subject. He has been a contributing author to the science assessment reports of the Intergovernmental Panel on Climate Change and the WMO/UNEP report on ozone layer depletion.

Bruce Hicks

Mr. Hicks is currently the Director of the Air Resources Laboratory of NOAA, headquartered in Silver Spring, Maryland. In earlier positions, he has worked at the NOAA/ARL Atmospheric Turbulence and Diffusion Division in Oak Ridge, Tennessee; at Argonne National Laboratory in Illinois; and at the Commonwealth Scientific and Industrial Research Organization (Division of Atmospheric Physics) in Aspendale, Victoria Australia. He holds a B.Sc. degree from the University of Tasmania and a M.SC, degree from Melbourne University, both in Australia.

Mr. Hicks's scientific interests relate to air quality and its prediction, and to the multi-media repercussions of air pollution. He has authored more than 200 scientific papers on topics ranging from air-sea exchange to Beryllium-7 in the stratosphere.

Michael J. Kurylo

Dr. Kurylo is a Research Chemist at the Chemical Science and Technology Laboratory of the National Institute of Standards and Technology (NIST). He is currently on assignment with the Office of Earth Science of NASA, as the Manager of the Upper Atmosphere Research Program. He has been the Program Manager for numerous NASA and international stratospheric and Arctic studies.

Dr. Kurylo has authored and co-authored numerous scientific and position papers and served as technical reviewer for several international assessments undertaken under the auspices of the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO). His research interests include gas phase kinetics and photochemistry, atmospheric chemistry, environmental chemistry, stratospheric ozone depletion and global change research. He has been the recipient of several awards including the National Oceanic and Atmospheric Administration's Environmental Hero Award.

Adaptation and Impacts Research Sub-Panel

Michael McCracken

Dr. MacCracken is senior scientist with the Office of the US Global Change Research Program (OUSGCRP). From 1997 to early 2001 he served as executive director of the National Assessment Coordination Office within the OUSGCRP, with responsibility for facilitating the US study of the potential consequences of climate variability and change. This study involved a national synthesis team, 20 regional studies, and 5 sectoral teams under the auspices of eight federal agencies.

Dr. MacCracken is on assignment to the OUSGCRP from the Lawrence Livermore National Laboratory. His scientific training is in climate modelling and he has been involved in assessments of climate change, nuclear winter, supersonic transport aircraft, and various natural causes of climate change.

Meteorology Research Sub-Panel

Chair – Paul Mason

Dr. Mason is currently Chief Scientist at the UK Met Office. Since 1991 he has been responsible for all research activities including the Hadley Centre for Climate

Prediction, the Numerical Weather Prediction activity, the Ocean Modelling section and Met Office Research flight.

Dr. Mason's research interests have included both modelling and observations of the atmospheric boundary layer and flow over hills. He is recognized as Fellow of the Royal Society for his contribution in that area.

Richard Anthes

Dr. Anthes has been president of the University Corporation for Atmospheric Research (UCAR), since 1988. He is a highly regarded atmospheric scientist, author, educator and administrator who has contributed considerable research in mesoscale meteorology. UCAR is a non-profit consortium of 66 member universities which award Ph.D.s in atmospheric and related sciences. UCAR manages the National Center for Atmospheric Research, in addition to collaborating with many international meteorological institutions.

Dr. Anthes has published over 90 articles and books and participated on, or chaired, over 30 different U.S. national committees. He has also received numerous awards for his sustained contributions to tropical and mesoscale meteorology.

Philippe Courtier

Dr. Courtier has been Deputy Chief Executive Officer of Météo-France, in charge of regional services and development, since 1999. Previously, he was Director of Laboratoire d'Océanographie Dynamique et de Climatologie, an oceanographic research lab. From 1995 to 1997 he was responsible for the operational meteorological programme at Centre National d'Etudes Spatiales, the French meteorological space agency. Previous to that he was a scientist in numerical weather prediction, at Météo-France and at the European Centre for Medium-Range Weather Forecasts, where his last position was head of the data division.

Dr. Courtier's scientific interest has been mainly in the field of data assimilation and the use of satellite data. He received his Ph.D. in 1987 and has published more than 30 papers in major peer-reviewed journals. He has been the recipient of several awards including the Buchan prize of the Royal Meteorological Society and the D'Abaddie prize of the French Academy of Sciences.

Eugenia Kalnay

Dr. Kalnay is the Chair of the Department of Meteorology at the University of Maryland. She was the Director of the Environmental Monitoring Center of the National Oceanographic and Atmospheric Administration's National Centers for Environmental Prediction from 1987 to 1997. During her time as Director of EMC there were major improvements in the NWS models' forecast skill. Successful projects including ensemble forecasting, 3-d and 4-d variational data assimilation, advanced quality control, coastal ocean forecasting, GCIP research with the Eta model, seasonal and inter-annual dynamical predictions were started or carried out during those years.

Dr. Kalnay's current research interests are in predictability and ensemble forecasting, numerical weather prediction and data assimilation. She is the author or co-author of many scientific papers and the recipient of many distinguished awards including Member of the National Academy of Engineering, the American Meteorological Society's Jule G. Charney Award and Foreign Member of the Academia Europaea.

Secretariat Support

Stuart McNair, of CSM Consulting provided secretariat support to the review panels.

APPENDIX B – PANEL CONTACTS

Climate Sub-Panel – On-Site Visit

Presentations

Briefing – *Michel Béland, Director General, Atmospheric and Climate Science Directorate*
Climate Research Overview – *Doug Whelpdale, Director, Climate Research Branch*
Canadian Centre for Climate Modelling and Analysis – *Francis Zwiers*
The CCCma Coupled Model – *Greg Flato*
Climate Prediction – *George Boer*
Climate Processes and Earth Observation Division – *Barry Goodison*
Boreal Ecosystem Research and Monitoring Sites (BERMS) – *Alan Barr*
The Mackenzie Basin Regional Climate System – *Ron Stewart*
Climate Monitoring and Data Interpretation Division – *Francis Zwiers*
Trends in Canadian Climate – *Xuebin Zhang*
Marine Wave Climate Reconstruction – *Val Swail*
Adaptation and Impacts Research Group (AIRG) – *Roger Street, Director, AIRG*
Science Assessment and Integration Branch (SAIB) – *Joan Masterton, Director, SAIB*

Interviews

Prof. Wayne Rouse, *McMaster University*
Climate Research Branch Scientists – *Diana Verseghy, Anne Walker, Walter Skinner*
Mr. Alf Warkentin, *Manitoba Water Resources*
Prof. Andrew Weaver, *University of Victoria*
Ulrike Lohmann, *Dalhousie University*
Prof. Jacques Derome, *McGill University*
Prof. Ted Shepherd, *University of Toronto*
Dr. Ken Denman, *Department of Fisheries and Oceans*
Ms. Shauna Sigurdson, *MSC, Prairie and Northern Region*
Prof. William Hsieh, *University of British Columbia*
Dr. Vince Cardone, *Oceanweather, Inc.*
Alex Manson, *Executive Director, Climate Change Bureau, Environment Canada*
Maris Lusis, *MSC, Air Quality Research Branch, Systematic Measurements*
Gérald Vigeant, *MSC, Quebec Region*

Final Questions and Clarifications

Doug Whelpdale
Michel Béland

Air Quality Sub-Panel – On-Site Visit

Presentations

Briefing – *Michel Béland, Director General, Atmospheric and Climate Science Directorate*
Air Quality Research Overview – *Keith Puckett, Acting Director, Air Quality Research Branch*
Systematic Measurements – *Maris Lusis*
National Atmospheric Chemistry Data Base – *Bob Vet*
Atmospheric Processes – *Cathy Banic*
Alert 2000 – *Jan Bottenheim*
Experimental Studies – *David Wardle*
Atmospheric Modelling – *Srinivasan Venkatesh*
Atmospheric Tracers – *Janusz Pudykiewicz*

Interviews

Bill Appleby, *Director, MSC Atlantic Region*
Roger Street, *Director, Adaptation and Impacts Research Group*
Joan Masterton, *Director, Science Assessment and Integration Branch*
Air Quality Research Branch Scientists, *Pierrette Blanchard, Jeff Brook, Mike Moran, Vitali Fioletov and Doug Worthy*
Bruce Thomson, *MSC, Pacific and Yukon Region*
Jeremy M. Hales, *Envair (NARSTO)*
Claude Gagnon, *Communauté Urbaine de Montréal*
Dan McGillivray, *Crestech*
Barry Greer, *Director General, Atmospheric Monitoring and Water Survey Directorate*
Jeff Harris, *York University*
PK Misra, *Ontario Ministry of the Environment*
Jim Drummond, *University of Toronto*
Réjean Michaud, *Canadian Space Agency*
Barry Stemshorn and staff, *Assistant Deputy Minister, Environmental Protection Service*
Mike Proffit, *Senior Scientific Officer, World Meteorological Organization*
Rick Burnett, *Health Canada*

Don McKay, *former Director, Air Quality Research Branch*

Final Questions and Clarifications

Keith Puckett
Michel Béland

Adaptation and Impacts Research Sub-Panel – On-Site Visit

Presentations and Interviews

Adaptation and Impacts Research Overview – *Roger Street, Director, Adaptation and Impacts Research Group*
Tony Clarke, *Senior Environmental Adviser, Canadian Section, International Joint Commission*
Les Lavkulich, *University of British Columbia*
Geoff McBoyle, *Dean, Faculty of Environmental Studies, University of Waterloo*
Rodney White, *Director, Institute for Environmental Studies, University of Toronto*
David Welch, *Parks Canada*
Adaptation and Impacts Research Group Scientists – *David Etkin, Stu Cohen and Brian Mills*

Meteorology Research Sub-Panel – On-Site Visit

Presentations

Briefing – *Michel Béland, Director General, Atmospheric and Climate Science Directorate*
Meteorological Research Overview – *Jim Abraham, Director, Meteorological Research Branch*
Recherche en Prévision Numérique – *Gilbert Brunet*
MSC Meso-scale NWP Strategy – *Jocelyn Mailhot*
MSC Meso-scale Modelling Community Activities – *Robert Benoit*
Coupled Modelling for Environmental Prediction – *Hal Ritchie*
Model Diagnostics – *Laurie Wilson*
Data Assimilation and Satellite Meteorology – *Dave Steenbergen*
Development of Variational Data Assimlation – *Pierre Gauthier*
Satellite Meteorology and Observation Usage in 3D-Var – *Clément Chouinard*
Ensemble Prediction and Ensemble Kalman Filter – *Peter Hontekamer*
Chemical Data Assimilation – *Richard Ménard*
Cloud Physics Research – *Stewart Cober*
Cloud Physics and Aviation Research – *George Isaac*
Radar Meteorology Group – *Norman Donaldson*

Interviews

Meteorological Research Branch Scientists – *Hal Ritchie, Steffan Bélair, Luc Fillion, Steffan LaRoche, George Isaac, Norman Donaldson*
Jean Guy Desmarais, *Director, CMC Development*
Peter Chen, *Director, CMC Operations*
Don MacIver, *Science Assessment and Integration Branch*
Peter Yau, *McGill University*
Gilles Babin, *Director, MSC Quebec Region*
Carr McLeod, *Director, MSC Ontario Region*
Bill Appleby, *Director, MSC Atlantic Region*
Tim Spangler, *UCAR (COMET)*
Brad Shannon, *MSC, Prairie and Northern Region*
Isztar Zawadzki, *McGill University*
Charles Lin, *Chair, Atmosphere and Ocean Science, McGill University*
Jack McConnell, *York University*
Terry Allsopp, *Director, National Weather and Climate Networks Branch*
Jean Jacques Rousseau, *Centre de Recherche en Calcul Appliqué (CERCA)*
Dave Wartman, *MSC, Atlantic Region*
John Carey, *Director, National Water Research Institute*
Pierre Dubreuil, *Director General, Canadian Meteorological Centre (CMC)*
Aviation clients/partners conference call: *Jim Riley, FAA; Jm Hoppins, Cessna; Dean Miller NASA; Andy Reehost, NASA; Claudius Laburthe, Airbus; Anil Shah, Boeing; Eugene Hill, FAA*

Final Questions and Clarifications

Jim Abraham
Michel Béland

APPENDIX C – SEA ICE R&D

The on-site visit for the MSC sea ice R&D review took place at the Canadian Ice Centre in Ottawa on January 28, 2002. The review panel Chair was Dr. Kim Partington.

Peer Review Report – Sea Ice Sub-Panel

Background

This external review of Sea Ice Research and Development is being undertaken in the context of a broad review covering the full scope of R&D carried out by the Meteorological Service of Canada (MSC).

Introduction

CIS (Canadian Ice Service) research and development (R&D) forms an important link between the operational arm of the CIS and the broader Canadian and international sea ice research community. As one of a number of international ice centres, CIS has played an important role in enhancing international cooperation. CIS leads in several research areas, notably in iceberg monitoring and development of ice strength and fast ice products. In spite of the small number of professional scientists and support staff in the Applied Science Division, a wide range of activities are covered.

This report summarizes significant aspects of MSC's sea ice research and, where appropriate, offers recommendations that could further strengthen the program. It should be noted that the panel was not in a position to review the technical merit of CIS modelling activities.

R&D Relevance

The research appears to be responsive to the operational needs of CIS and its clients. The R&D program has both stimulated the development of new products and has responded to feedback from the operations group at CIS. Furthermore CIS is aware of, and planning for, the availability of new sensors that will be useful to CIS operations.

Quality of R&D

The R&D is innovative and is recognized as such internationally. It does not produce pure science results, except indirectly through support for field programmes and production of climatological data from the ice charts. Instead, the research is focused on the application of techniques to assist operational monitoring of ice conditions at CIS. Unique areas of research include iceberg monitoring techniques and the development of an ice strength product, which may well generate interest from other ice services.

Some areas of sea ice research have been less successful than others, as in development of an ice classification system from SAR data, but CIS has altered the focus of its efforts in light of this. The Panel is concerned that CIS does not routinely articulate and monitor the benefits (planned and actual) of each of its research activities. An example of this is field work performed by CIS specialists. Without clear objectives for this work it is difficult to establish how beneficial this activity is to the CIS.

1. ***The Panel recommends*** that CIS establish operational and/or scientific goals (metrics) for their research activities and record their success in meeting these goals.

R&D Planning

CIS has articulated a plan for future R&D based on anticipated sensors and promising techniques. However, this plan does not appear to be formalized. Given the range of new sensors anticipated and changes in emphasis in some areas of R&D (e.g. towards longer range forecasting from short-range forecasting, development of multiple polarization SAR techniques), it would appear that a more formal plan would be of value. Such a plan could help CIS to avoid activities being driven by short-term requirements, or perhaps by the interests and expertise of existing partners.

2. ***The Panel recommends*** that CIS formalize its vision for its products and services in 5-10 years time. This would provide a guide and help establish priorities for CIS R&D. Such a plan would require as input a summary of expected data sources, evolving IT technologies and user requirements, and should be developed with participation from within and outside CIS. This plan should be used to guide the development of international collaborations for specific projects, for example with the US National Ice Centre and Danish Meteorological Institute.

Coordination

CIS has made important advances in coordination of activities with the international community through the US-

Canada Joint Ice Working Group and the International Ice Charting Working Group. In addition, there appears to be good coordination of requirements and activities within CIS itself. One specific area that appears to need improved coordination is data assimilation.

CIS has articulated a vision of moving toward model-based ice charts based on data assimilation. This is a commendable goal and, if implemented, will ensure that CIS plays a leading role internationally in the development of sea ice monitoring capabilities. For this to be a realistic goal CIS needs to play a role within a broader, coordinated data assimilation programme within MSC that addresses assimilation of ocean and ice data in general and interacts with the meteorological programme, where data assimilation is an integral component of forecasting.

3. ***The Panel recommends*** coordinated development of data assimilation techniques to allow pooling of expertise and resources (e.g. computing resources) and to realize benefits both within CIS and in other MSC programmes. This activity would require a detailed plan, as well as an associated budget forecast and a formal review process.

Publicity and Outreach

The CIS has an active education and outreach program that has, through collaboration with industry, developed an innovative ice tutor tool. Although there is no evidence that the staff are not up-to-date on relevant scientific developments, the combination of high work load, shift work and relatively small staff size create a real danger of operational staff and techniques becoming disconnected from relevant research.

4. ***The Panel recommends*** that CIS develop suitable training plans to ensure that staff are aware of developments in research related to sea ice. Subject areas should include new sensor technologies, current thinking on climate change (and implications for Canadian offshore activities), and ice forecast algorithms. Good use could be made of workshops organized by CIS, attendance at key international conferences followed by talks to the rest of CIS, visiting scientist seminars, etc. Specifically on the subject of climate change, the CIS should look to the CRYSYS team to provide relevant information.

CIS has generated a useful resource through its digital record of sea ice in the Canadian region from 1968. The logical next step would be to undertake a systematic study of the record to identify significant features and to assess implications for future operational activities in Canadian waters.

5. ***The Panel recommends*** that CIS prepares a high profile paper, with appropriate collaborators, in which the full scientific and operational implications of the record would be explored, as a service to the science community and as a tool for educating CIS personnel on recent evolution in ice conditions.

Sub-Panel Chair

Kim Partington

Dr. Partington is currently Managing Director of Vexcel UK, Newbury, England. His previous positions include Manager of NASA's Polar Research Program and Senior Scientist at the US National Ice Center.

Dr. Partington has been involved since 1984 in polar research, in academia, university and government positions. His interests have been focused on the use of satellite earth observation data to assist in understanding ice conditions in the Arctic, either for operational purposes or for answering scientific questions. His current interests include the use of polarimetric radar data in classifying sea ice and the use of various datasets in helping to characterise patterns of variability in late twentieth century Arctic ice conditions.

Sea Ice Sub-Panel On-Site Visit – January 28, 2002

Presentations

Overview of MSC Sea Ice R&D – Bruce Ramsay
Numerical Ice Modelling – Tom Carrieres
Remote Sensing for Ice Operations – Dean Flett
Ice Science Applications – Roger de Abreu
Ice R&D Within Meteorological Research Branch – Mohammed Shokr
Ice Science Education – Sheila Bourque

Interviews

Fiona Robertson – Canadian Coast Guard, Ice Breaking
John Falkingham, Marie-France Gauthier – CIS Operations
David Barber – University of Manitoba
Peter Smith – Bedford Institute of Oceanography was unavailable