A Vision of Atmospheric Sciences for the Next 10 Years (2005-2015)

The
Report from the Atmospheric Environment (AE) Community

5th CSA –AE Workshop
Banff Centre

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Picture Caption in the color version

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Executive Summary

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The Canadian Space Agency held its 5th Atmospheric Environment Workshop in Banff from May 5 to 7, 2005. The aims of this Workshop were:
(1) To review Canadian progress in the field of Atmospheric Sciences,
(2) To facilitate communication between the diverse members of the A-E community,
(3) To look to the future of "space-based" missions,
(4) To consider how Canadian activities align with international efforts, and
(5) To allow younger researchers to help shape the discussions and therefore the future of their research programs.

The overarching objective of the Workshop was to identify a **"Canadian Vision for Atmospheric Sciences for the next 10 years"**. This Workshop Report provides a background for the event, summaries of the presentations and discussions, and finally presents the resulting Recommendations with suggested Actions.

The dates and location were chosen in consultation with the Atmospheric Environment community, and became sequential with the Canadian Middle Atmosphere Model (CMAM) Summer School (May 7-13, 2005). This latter coincidence minimized total costs and maximized attendance, particularly of students and post-docs.

The Program and Agenda were organized by Prof. Alan Manson (Co-Chair of Advisory Committee to the CSA, SAEAC, and Chair of the Atmospheric Environment (AE) Committee) and Dr. Stella Melo (Program Scientist to the AE), in consultation with members of the AE Committee and Dr. Rejean Michaud (Director of Solar-Terrestrial and Atmospheric Sciences). Approximately 80 persons registered and attended: Professors, Research Associates, PDFs, Engineers, Graduate Students, Industrial Representatives and MSC/CSA Scientists and Administrators.

The Program was built around four Theme working groups:

*Ground-Based (Arctic) Observations;

*Remote Sensing from Space;

*Modelling of the Earth's Atmosphere;

*Monitoring and Prediction.

The Theme working groups were tasked to identify present activity, relate that to the 2002 status (Workshop #4) and to discuss activities, opportunities and goals for the next 10 years. Minutes were kept with Summaries presented in Plenary session, where refinements could be developed. Reports of ~3 pages are contained here as Appendices: this was the first time the Ground-based, Remote Sensing, and Modelling communities had been tasked to do this at a CSA Workshop, so the reports are unique and timely. Participants were asked to choose to work in the dominant Theme of their research lives.

There were then 5 cross-thematic Groups which identified the essential linkages between the 4 Themes, how to achieve them, and to formulate goals for the next 10 years: a "Vision for Atmospheric Sciences" (as requested by Director Dr. Michaud, and desired by Drs. Melo and Manson). The Programs and Agenda are in Appendix A.

The Theme and Group Leaders were of superior professional calibre, the participants energetic and productive, and strong consensus was reached on a number of highly significant issues. The Reports coming from those Themes and Groups (Appendices B-J) provide clear support for the inherent quality and directions of the Programmic activities within the Solar-Terrestrial and Atmospheric Sciences area of the Space Sciences Program, which have been developed over the last 10 years; they also show a unified desire for innovative and effective refinements within those. It is considered that these can be initiated without unreasonable cost, yet lead to greatly improved quality of science and training of HQP, engagement of the community, and understanding of atmospheric processes. Three major programmatic thrusts, of a type expected from this community within the 10 year time interval, are also included. The following is a summary of the Recommendations provided in Section 4 of this report:

- **Enrichment of the Scientific Satellite Missions** to include integration of gb, modelling and monitoring-prediction activity (the latter being a funding issue) from the beginning,: and the optional use of a greater variety of system-testing vehicles;
- **Continuation of the Small Payloads Program** for balloons, aircraft, rockets, and micro-satellites (this may be linked to the above Enrichment);
- **Enhancements to the existing array of professional training processes** and programs; and establishment of mechanisms to provide career paths for essential engineers and specialists;
- **Improved effectiveness in raising public awareness** of activities and research in the area of Atmospheric Sciences, and of their great societal value;
- **Stronger and more focussed lobbying** thrusts involving Governmental Officials, Committees and Ministers;
- **The development of a coherent approach to deal with multi-agency funding issues**

  There was also agreement upon three major Programmic thrusts:

- **Development of a data-archiving process and "facility"**, in partnership with the MSC, to both contain and allow future alternate processing of data from all missions (past & future); and to consider the development of a strategy for an appropriate and unique Canadian "meteorological remote sensing" capability;
- **The "Chinook Mission"**, which would include the SWIFT interferometer to measure global stratospheric winds and ozone, and complementary system(s) of a more modest nature. The community requested full involvement in the planning of the mission, which should contain essential integrative elements of 'Mission Enrichment' discussed above.

- **A “niche” satellite mission to study complementary processes associated with Climate Change**, within the decade 2005-15. A community workshop will be held (2005 was requested) to consider responses to an Announcement of Opportunity, and a mission chosen that maximizes both scientific benefits in relation to cost and involvement of the atmospheric community.

The Workshop was notable for the excellent spirit of goodwill, energetic participation, and productivity of the community. There were presentations on Thursday summarizing the present status of existing missions and activities (attached CD to this Report). Also, there were poster sessions on Friday (lunch, dinner and evening): these were of excellent international quality and generated strong scientific exchanges which permeated the Theme and Group discussions and reports. The community expresses thanks to the staff of the Space Science Program and Director-General David Kendall for the opportunity to hold this Workshop and for the financial support (accommodation and food) supplied to graduate students, PDFs and Research Associates.

1.0 Overview of Science being done now with CSA Support

The Workshop began on Thursday afternoon with presentations by scientists and CSA-SSP Program staff, and continued after dinner with a presentation by the Director-General of the Space Science Program, Dr David Kendall. These are available on a CD contained in a pocket at the back of this Report.

The reader who wishes to be updated in this area is encouraged to peruse these. They are an essential ingredient and background to the work done by the Workshop participants on the Friday and Saturday.

2.0 Theme Working Groups and Reports

The four Theme Leaders provided video-summaries on Friday after a full morning of discussion and planning. A more detailed ~3 page version of each is included as a Report in the Theme appendices. **The reader is encouraged to read these for further insights and information.** Each summary was produced during the morning deliberations, using either real-time computer-video presentations or “paper-boards”. As such, and given the calibre of the Leaders and participants, they represent a strong consensus view of the Theme’s activity and “vision”.

The range of science supported by the SSP of the CSA since 1990 has been comprehensive, and includes the chemistry of the troposphere, stratosphere and mesosphere-lower thermosphere; aerosols; clouds of the troposphere but also polar stratosphere and mesosphere clouds; and dynamics of the mesosphere-lower thermosphere. An Annual Report will be provided to the

Advisory Committee on this work (2005) and elements of that will also appear in the website of the CSA, www.space.gc.ca The research is highly collaborative internationally and contributes significantly to the study and increasing knowledge of global atmospheric processes. These processes involve weather and climate variability, effects of anthropogenic and solar changes, pollution, air quality, and ozone and greenhouse gases (GHGs).

2.1 Remote-sensing from space

The activity has involved a number of unique Canadian systems flow in Canadian (CSA), American (NASA) and Scandinavian (led) satellites.

Missions since 1990 include these:

- WINDII — Wind Imaging Interferometer, Prof. Gordon Shepherd (PI), York University
- MOPITT[1] — Measurement of Pollution in The Troposphere, Prof. James Drummond (PI), University of Toronto
- OSIRIS[1] — Optical Spectrometer Infra-Red Imaging System, Prof. Edward Llewellyn (PI), University of Saskatchewan
- ACE[1] — Atmospheric Chemistry Experiment, Prof. Peter Bernath (PI), University of Waterloo

[1] Operational now

In addition, CSA has supported remote sensing from “near space” through the MANTRA stratospheric balloon program (Prof. Kimberly Strong (PI), University of Toronto).

Many papers have been written over the last 15 years involving these instruments, and much national and international collaborative activity has resulted. Posters (several authored or co-authored by senior graduate students) that used their data were presented at the Workshop.

The report from the “Remote-Sensing from Space” Working Group is provided in Appendix B. The Leader was Professor Ian McDade (who has been involved with three of the Missions above), along with ~30 other Professors, Engineers (Universities and Industry), Scientists (MSC) and Graduate Students. Professors Llewellyn and Bernath were also involved; Professors Shepherd and Drummond were involved with the “Ground-based” theme, and had strong input into the “Remote-Sensing” theme during the Group activities. Participation in the Working Group was full and constructive. Specificity regarding the details of measurements and systems was not required, and represents the innovative ‘intellectual property’ of the participants (the latter will be provided in subsequent mission selections.)

It is appropriate to note that the cost of a Mission is dominated by the development of the ‘observational system’ [thus far using visible or infra-red radiation], data-algorithm design and testing, incorporation into the ‘bus’, launch, operation of the system in space, validation (a modest cost usually, thus far involving recognized ground-based systems or balloon systems) and analysis of data to the stage that initial papers can be published in premiere journals. This cost is provided by the CSA. This is consistent with the mandate of the CSA to carry out observations from space. Subsequent costs of system operations have traditionally been included in the CSA budget for the Mission; but the support of scientists and students who carry out the essential analysis of data and their incorporation into research papers requires the PI and 'science team' to obtain research grants from NSERC and/or CFCAS. This second stage may involve 5 or more years. An agreement between NSERC and the CSA regarding funding is desirable from Mission-initiation, but such agreements have a life-span shorter than the circa 5 years between missions, or the lifetime of Missions. This 'funding' theme is included in the Concluding section of the Report.

The reader is referred to the Theme Report in Appendix B for more details. However, it will be noted that although cross-thematic discussions were still to follow in the Workshop, there is desire for the testing of mission-systems in aircraft, balloons or small rockets; 'small' projects could provide these opportunities (consistent with the "Small Payloads" program-element included in the later Consensus Recommendations). The method and "vehicle" would depend upon the mission and the nature of the system. However, experience has shown, here and elsewhere, that optimization of the quality and quantity of data can be enhanced by such additional testing. The following are extracts from the Report in Appendix B:

The Theme Working Group targeted these items:

'***Improved Atmospheric Science for Improved Human and Canadian Welfare'*** as the major thrust for future Remote Sensing from Space with emphasis on:

1. Near ground level pollution (*i.e.*, tropospheric air quality, surface sources of pollution, chemical weather forecasting) – this emphasizes ***the air we breathe now!***

2. Climate change (trends, carbon cycles, composition & chemistry, global radiation budget) – this emphasizes ***the air we will likely breathe in the future!***

3. Atmospheric coupling & dynamics (atmospheric waves, winds, temperatures throughout the middle atmosphere) - this emphasizes ***the fundamental science knowledge we need to deliver on topics 1 & 2 above***

Recommendations from the Working Group:

That there be a **'balanced mixture'** *of large and small projects with small as potential candidates for the large:*

● *Small to enhance student training with hands-on activity*
● *Small to allow riskier innovative activity*
● *Small to allow for better continuity*

● *Large should preferably be Canadian-led science missions with Canadian instruments and guest international instruments.*
● *Large should NOT be Canadian-provided components on international missions with limited or no clear Canadian scientific involvement.*

2.2 Ground-Based (gb) (Arctic) Measurements

In addition to measurements (ground-based) *in direct validation of satellite experiments there are also measurements that can assist with the understanding of satellite measurements and measurements that provide data that satellite cannot obtain, but which are important to improve the utility of those measurements.* (This phrase comes from the Introduction to the Theme Report in Appendix C)

The Canadian community is rich in Professors and scientists who develop and operate gb systems, and who collaborate with each other and the International community to provide global studies of atmospheric processes. While these are usually of high time resolution (minutes) and continuity, the global 'networks' are irregularly spaced in longitude and latitude, with many parts of the planet (e.g. oceans) unobserved. In contrast space-based (sb) systems have significant global coverage (all longitudes and a large range of latitudes, usually equator to high latitudes, if not the pole), but a precession rate that may require many weeks for all local times at a given location to be observed. Depending upon the altitude and nature of the observations, a combination of gb and sb systems is increasingly attractive to allow more scales of motion and temporal variability to be assessed. (E.g. NASA-TIMED [Thermosphere Ionosphere Mesosphere Energy Dynamic]s mission).

Outstanding systems include these:

Radars (VHF, MF, Meteor detection) for tropospheric and mesosphere-lower thermosphere (MLT) studies: Profs. Wayne Hocking, Alan Manson, John MacDougall;

Lidars for troposphere to MLT (100 km) studies: Profs. Bob Sica, Jim Whiteway, Tom Duck;

Optical imagers/spectrometers for MLT studies: Profs. Gordon Shepherd, Marianna Shepherd, William Ward, Bob Lowe;

Surface radiative environment and sampling: Profs. Jim Sloan, Norm O'Neill, Bruce McArthur;

Lower (troposphere) and middle atmosphere composition: Kim Strong, Kaley Walker, Tom McElroy, Hans Fast.

Within the University community, the operation of these systems has depended almost exclusively upon 'Discovery Grants' and 'Research Tools and Instruments' and they operate continuously or for campaigns. Many of the above systems and scientists have been involved (at their own NSERC cost) with validation and collaborative activity with some sb missions (e.g. WINDII and HRDI on the UARS (NASA's Upper Atmosphere Research Satellite) and TIMED) independently of the CSA. There has also been participation in validation campaigns for Canadian missions such as ACE with the recent campaign at Eureka funded by the CSA and MSC.

The Canadian Network for the Detection of Atmospheric Change (CANDAC) is a new association of university and government scientists who are actively attempting to build up the ground-based capability in Canada for the purpose (among others) of providing a more stable and comprehensive capability for satellite validation in Canada. They are currently focussing effort on the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka as a primary "anchor point" for research measurements and satellite validation

The Report from the Ground-Based (Arctic) Measurements Theme Working Group is provided in Appendix C. The Leader was Professor James Drummond (also PI of MOPITT), along with ~15 others. They formed an experienced and representative group; and reports from 3 prominent Professors (who were unable to attend) were provided to the Leader before the workshop and presented to the working group at the workshop. The reader is referred to that Report, but a few comments are appropriate first.

This is the first formal CSA-linked Report from persons with strong interests and involvements in ground-based activities., and there is a strong Vision. The major point to come from the Theme discussion is that validation is not an optional "add-on" to a satellite mission; it is an integral part of the science of the mission and should therefore be included in mission-planning from the earliest stages onwards.

The concept of "anchor sites" was discussed as a good model of how the field should develop in its capacity for satellite validation and independent science. The CANDAC/PEARL site could serve as a (non-exclusive) model for such sites.

Recommendations (Appendix C):

1) *That the CSA support the installation of a small number of "anchor sites" to provide additional scientific information in support of space experiments.*

2) *That the CSA consider the issue of required ground-based assets for a space project at an early stage in the planning to permit sufficient time for the definition, installation, activation and data analysis from such assets before the space segment is launched.*

3) *That the CSA continue to support the efforts of the community to acquire ground-based assets in support of atmospheric science through such mechanisms as CANDAC (Canadian Network for the Detection of Atmospheric Change) and similar networks.*

2.3 Modelling of the Earth's Atmosphere

The Canadian community is most fortunate to have an outstanding group of scientists and students (university and MSC) associated with the CMAM general circulation model. The PI is Prof. Ted Shepherd, who also was Leader of the Theme working group. This is one of the most successful and comprehensive GCMs in the world: there is a version extending to ~ 100 km, which may operate with or without "interactive chemistry", and an extended version that reaches into the thermosphere (up to ~ 200 km).

A variety of funding mechanisms have been used: NSERC, CFCAS, and with the Data Assimilation aspects (CMAM-FDAM), support from the CSA.

Another complementary model has appeared in the community (GEM-AQ, Dr. Jacek Kaminski and Prof. Jack McConnell) and the Theme working group was able, for the first time, to discuss and plan for the complementary use of these two powerful systems. Modelling teams have an international history of working together to inter-compare and refine (in unique ways) their models, and it has been desirable to develop this atmosphere of trust and co-operation within Canada.

The Report from the "Atmospheric Modelling" Theme Working Group is provided in Appendix D. There were ~20 persons in the Group, including very experienced scientists, Professors and graduate students.

Again the Report is detailed and clear in its direction: it also favours and recommends involvement of 'theoreticians' and their 'models' in a Satellite Mission from its inception, and throughout the development and scientific-analysis stages of the Mission. Modelling can now provide additional guidance on optimization of a Mission: the measurements, their sampling in space and time, including the seasons and hemispheres of the planet. Spacing and locations of gb systems involved in gb-sb integration can also be suggested from modelling experiments. Data assimilation has now been developed for CMAM-FDAM, and will be available for all future missions. This aids in both model development and in the diagnosis of global atmospheric processes. The following is extracted from the Report:

How can modelling contribute to the future plans of the CSA? Modelling (and data assimilation) is the integrator of measurements. It allows one to estimate observation and representativeness errors, help in the monitoring of observations and calibration of instruments, provide value-added products by merging different data types, validate data, and provide scientific interpretation of data. In this respect, ground-based data is very important for bias correction. At the same time, comparison with (and assimilation of) measurements improves the models, which leads to improved understanding of the atmosphere and an improved predictive capability.

The following Questions are answered in the Theme Report (Appendix D); in some cases these become Recommendations to be considered by the CSA-SSP in revising AOs which are issued for Satellite Missions and other SAEAC-AE programs. There is one recommendation provided below, which is consistent with the notion of Integration of Themes, which permeates this Workshop Report:

How can modelling contribute to the future plans of the CSA?
How do we best exploit and enhance CMAM-FDAM?
How do we best exploit and enhance GEM?
How about other models?
How do we tie modelling more strongly to MOPITT, OSIRIS, ACE, CloudSat, and CANDAC?
How do we link to non-Canadian missions? We need to develop a mechanism for funding
How will modelling support Chinook?
What lies ahead internationally for modelling?
How to get modelling in at the outset in new missions (e.g. CO_2)? **Make it a requirement!**

2.4 Monitoring and Prediction

In comparison with her colleagues in the G8, Canada does not have the organizational ability or structure to develop 'meteorological remote sensing' systems. Although Canada has 'research' satellites associated with understanding atmospheric processes, Canada does not have 'operational' satellites providing information in real time for data assimilation. This latter is required by the MSC to improve forecasting and monitoring capability for Canadians. Clearly the CSA and the MSC need to work together to develop strategies to resolve this problem and provide an appropriate and unique Canadian solution.

The Report from this Theme Working Group is in Appendix E. The Theme was led by Dr. Bruce McArthur, Head of the Experimental Studies Division within the Air Quality Branch of the MSC. There were ~10 persons who had input into this Report, some of whom also spent time in the 'Modelling' and 'Remote-sensing' Theme working groups. Careful reading of this report is encouraged, as it is rich in detail. It provides many suggestions and mechanisms whereby greater complementarity can be achieved between the needs of the MSC and CSA-AE programs. Significant questions, highlights and inferred recommendations are given below:

1.) Why are scientific satellites not more effectively used in real-time operations? (Data archiving and analysis needs better support; all possible users of data require early involvement in the mission; missions would profit from related enhanced optimization; satellite instruments should be science-driven.)

2.) The high value of ground-based observations was stressed: validation for non-Canadian satellite instruments could be provided; g-b observations provide bridging between satellite missions; g-b observations may powerfully complement the space-based observations.

3.) Modelling with data-assimilation has value for assuring the quality of data from individual observing-sites, and can/should be used more often/effectively.

4.) The Theme working group recommended the establishment of a "Centre for Data Analysis", and provided a number of responsibilities for the new facility. It was noted that this would require a high level of coordination between the CSA and the Meteorological Service.

3.0 Group Activity and Report

The Workshop began the cross-thematic Group discussions after the mid-afternoon Beverage Break on Friday, and finished with plenary sessions on both Friday and Saturday morning. Five Groups containing 12-15 persons each spent 90 minutes discussing the essential linkages between the Themes and developing goals for the next 10 years. Five persons representing each of the four themes were named to each Group to ensure balanced and (thematically) informed discussions and Reports. Leaders were Professors William Ward, Doug Degenstein, Kim Strong, Dylan Jones and Dr. Tom McElroy: four of these persons have significant CSA satellite mission experience, and the third is a 'modelling specialist'. The Reports are the result of refinements following Saturday's Plenary, which also contained a consensus-building conclusion.

The Reports are in these Appendices, and highlights or headings are provided below:

Appendix F: An "Ideal Mission life cycle"

Appendix G: Data Archiving, Analysis and Usage; Climate Change (space-based, ground-based, models); Public Awareness; Funding (Chinook and beyond).

Appendix H: Theme Linkages, a 'Wish List for the Decade' (Big and Small missions, Data and People; Integration of modelling and ground-based into missions from the start; New Technology; Collaborations.

Appendix I: Major research focuses (multi-theme); Observational Requirement; Modelling; Data Archiving.

Appendix J: Theme synergies; Data issues; Thrusts [Climate Science; Regional impacts of Change; Canadian role]; a Climate Change Mission; Continuity.

It is interesting and very useful that although there is consensus on many issues, and futures, each Report has a complementary approach. **Careful reading is encouraged, especially by those who will be involved in Action on the Recommendations.**

4.0 Synthesis, Consensus Items with Recommendations and Actions

The Chair of the AE Committee (Prof. Alan Manson), who also chaired the various Plenary Sessions, provided a Consensus Document on the Saturday morning. About two hours were spent in plenary discussing, refining and adding detail to the Document. The Session ended at 12:20 p.m.

An essential part of this Document is the featuring of **Recommendations** and corresponding **Actions.** Without this, the Section containing this Document has no lasting value. The Chair refined this Document for this Workshop Report, however, the Recommendations were already inherent in the Document at 12:20 Saturday May 7 and the procedural Actions that follow in each case were also sought during the final hour of Plenary. This Document, which is now shown below has also been appraised for balance and content by the 9 Theme and Group Leaders (the Co-authors of this Report).

4.1 Consensus Items emerging from the Theme and Group (cross-Thematic) Reports.

Enrichment of Future Scientific Satellite Missions

Recommendation: that members of the broad AE community have the opportunity to be more comprehensively involved in future missions: scientifically, technically and observationally. This requires an enhanced role for ground based (gb), modelling, and monitoring and prediction (if $ possible) activities for each mission.

Discussion: this integration was inherent in Theme reports, endorsed by all Groups: quotes from Groups include those in an "Ideal mission life cycle"; to "Integrate modelling and gb from the start"; and development of a "gb satellite of core instruments". **The rationale** was that the science coming from such missions will be enhanced in quality and lead to deeper understanding.

On the related matter of funding: the missions, whose outputs are atmospheric process understanding and knowledge (science and technical), involve funding from the CSA (including 'validation' and the 'preparation of data until ready for publication purposes', and subsequent operations) and from NSERC, etc. (the latter can include funding for sb, gb and modelling scientific activity). Early inclusion of scientists from these latter fields in the Science Team as Co-investigators will allow NSERC etc. funding to be sought for comprehensive science.

Action: that the CSA staff (those within the Solar-Terrestrial and Atmospheric Sciences theme, Director Rejean Michaud) consider the implications of this recommendation, and how it should be implemented within the AO process; and that related discussions should take place at the SAEAC-AE meetings. The community will be effectively involved, and engaged appropriately. (There is support in Appendices C-J for this Recommendation.)

Enhancement of Development Processes for Advanced Studies and Satellite Missions

Recommendation: that the Small Payloads Program for balloons, aircraft, rockets, and micro-satellites be continued; and that there be the option of testing observing systems (in aircraft, balloons, rockets or ground-based platforms) for Satellite Missions to enhance the reliability and operation of the system once in orbit. This could also positively affect the development and validation stages.

Discussion: The **rationale** was for significant benefits to HQP training and science quality and penetration. This Small Payloads Program is vital for "small science", instrument development, training of HQP, and maintaining continuity in the Atmospheric Environment community, particularly if the community is to be limited to two larger satellite missions over the next decade. There is the possibility that the programmic-mechanism for the desired "testing" of systems for Satellite Missions could be achieved through the "small payloads" program.

Action: that the CSA staff (those within the Solar-Terrestrial and Atmospheric Sciences theme, Director Rejean Michaud) consider the implications of this recommendation, and how it should be implemented within the AO process; and related discussions should take place at the SAEAC-AE meetings. The community will be effectively involved, and engaged appropriately.
It was noted that response to this addition to the AOs should be optional for the Mission team, and if used would possibly be associated with the notion of enhanced HQP training. (There is discussion and support from Themes B and C and Groups F-I.)

Enhancements to the Space Science Program's HQP Programs

Recommendation: that expansion of the Scholarship supplement to include other than NSERC Scholarships be considered; and that the establishment of mechanisms to provide career paths for essential engineers and specialists be again attempted.

Action: This will be an agenda item in upcoming SAEAC-AE meetings. (There is discussion on this matter in Appendices G-J.)

Agreement with the offer of the CSA to facilitate the management of data archiving; but that in partnership with the MSC there should also be consideration of a strategy for "operational satellites"/ meteorological remote sensing

Recommendation: that in partnership with the MSC, a data archiving process and "facility" be developed, to contain and allow processing of data, and to allow processing of already archived data by subsequent and alternative means. As data may be used in "reanalyses" many decades hence (witness the NCEP/NCAR and ERA40 reanalyses), the required timeframe is very long-term. Those involved with the facility should also consider the development of a strategy that would provide Canada with an appropriate and unique "meteorological remote sensing" capability.

Discussion: The **rationale** was that this was an investment needed for Climate Change futures; and to maximize the value of investments made in Satellite Missions. The facility should also deal with "operational satellite issues". It was noted by Director-General David Kendall, that this was a major item, and would require a Memorandum to Cabinet.

Action: a working group will be formed to begin moving this process forward (William Liu and Thomas Piekutowski from CSA; Bruce McArthur, Pierre Gauthier and Tom McElroy from MSC). (This is new issue for the AE community and it was discussed in the Theme report of Appendix E; thereafter all Groups (Appendices F to J) discussed the matter and supported this Recommendation.)

Public awareness

Recommendation: that some % of Satellite Missions and Advanced Studies contracts issued be for this purpose, and included in the plans for each proposal.

Discussion: The **rationale** was considered obvious, in our efforts to raise the visibility of the work done with the CSA etc. It was noted that the CSA web site could have a role in this (Stella Melo will be active in this area); at the science level the SPARC Newsletter has growing value [contact Diane Pendlebury]; and other newsletters and bulletins (e.g. SCOSTEP-CAWSES). This material can also be a useful resource for science reporters.

Actions: The CSA communications specialists could be asked to organize an opportunity to train us in public awareness; cost and time for the Professors is an issue for that option. The Chair also asked Tom Piekutowski to talk with Rejean Michaud about having this (a visit from a communications person) as an item on the SAEAC meeting (June 9th). (Although only overtly discussed in Appendix G, this is a well known issue and was well supported in Plenary.)

Lobbying

SAEAC has been active on this since December, with useful activities and responses from politicians. Don McDiarmid is on the agenda for June 9th SAEAC meeting, to discuss lobbying before the next federal budget.

Actions: it was agreed that lobbying should be internal to CSA (there are new persons to talk with); and that there should be political contacts made by CSA-SSP staff, by University-SAEAC persons, and other Space-related-Agencies.

Funding issues: NSERC and other Granting agencies

Recommendations: that there be communication with NSERC regarding the future of community members within GSC 09; that the community devise a cohesive approach to deal with multi-agency funding issues; and that there be further input to Dr Carty's office regarding the Discussion Paper on Major Science Investments

There was **discussion** about these items:

1. Could SAEAC or a group of senior scientists craft a letter to NSERC (independently of CSA, and perhaps first to Kate Wilson) arguing for movement of members of the community from GSC 09 (because it is too broad to properly evaluate our proposals)?
2. Regarding multi-agency issues, the Dr Kendall noted this: Dr. Carty has started a monthly dinner discussion between heads of funding agencies. He suggested that this was a good forum for discussing liaison/gap problems between agencies. He further suggested writing letters to heads of agencies, copied to Dr. Carty, identifying the problems.
3. The 'Major Science Investment' Discussion Paper was discussed. Drs Kendall and Manson have been in communication with Dr Carty's office. Dr Drummond has materials ready for sending to the office. There will soon be a second draft of the Document containing refinements due to many inputs from the Canadian broader community. AE community input will eventually be appropriate.

Action: the various processes/letters required will be discussed at the SAEAC-AE meeting (June 8-10). (This is a well known issue within the Community; the Appendix G Report discusses it more, and there was strong Plenary support for the Recommendations.)

Satellite Missions associated with the Atmospheric Processes of Climate Change

1) Chinook

Recommendation: The mission, while appropriate to Climate Change/Atmospheric Processes issues, and generally supported by the Workshop Participants, requires development by the Science Team. The AE Committee and the Science Team should be in good communication. It is considered essential to integrate appropriate modelling, ground based and monitoring-prediction (the latter if possible within the budget) activities at the beginning of the planning process, and at the Science Team (co-investigator) level, so that science is enhanced and science-NSERC etc funding is adequate for the life cycle of the Mission. The impact of the Chinook Mission upon subsequent Missions must be clarified with the community.

Discussion: There was discussion on Chinook throughout the workshop by the Theme and Group working groups; the presence of the SWIFT instrument in Chinook, as the major system, was expected and supported. The Theme and Group Reports should all be read on this matter. However the above usefully summarizes the concerns and wishes of the community present. It was noted that a Workshop on this Mission is likely to occur; and that the Instrument complement is not frozen. There was strong and consensus concern about the cost of Chinook and the effect upon other Missions over the next 10 years; it was considered that the Mission must be optimized for scientific return.

On Space Science Program funds: the Director General noted that while the pool of available money for science is not really fixed, big missions (perhaps beyond Chinook — see below) require engagement of industry for necessary lobbying.

Actions: the Science team mentioned by Stella Melo will be active (May-June); and this will be an agenda item for the SAEAC-AE meeting on June 8th. (All Theme Reports and four of the five Groups comment on/support Chinook in principle.) The community will be effectively involved, and engaged appropriately.

2) Niche Mission

Recommendation: that the AE community have the opportunity later this year (2005) to fully discuss the opportunities for such a Mission in the 2005-2015 interval. The scenario could include responses to a LOI, preparation of responses to an 'internal AO' for Mission description (which would have appropriate integration of modelling, ground based and monitoring-prediction Themes and scientists), reviews of responses, and a Workshop for the community to discuss and provide recommendations. Broad community engagement is desired to optimize the quality and quantity of science in any chosen Mission. The planning and the related search for CSA funds must begin soon; candidates need to be financially supported following the LOI process.

Discussion: There was useful and focused discussion at the end of the Saturday's plenary leading up to this recommendation. Input from experienced Mission scientists and CSA Staff was involved. It was noted that several Mission possibilities already exist within the Remote Sensing community. There is also an upcoming 'Climate Science and Measurement' workshop in mid-May (Tom McElroy, MSC) where aspects climate and carbon cycle measurements will be discussed. The Director General also informed us that there will be a Mission concept RFP (joint Space Science/Space Technology) to be released in several months. Its scope is for a "small" satellite to follow 4-5 years after Chinook, (~$100M, 350-500 kg payload).

There was discussion in several Themes and Groups about the merits of Missions comprising 'small' and 'big' systems. This is a topic that has its proper place within the Mission descriptions to be presented at the proposed Workshop.

It was strongly noted that the Government should be encouraged to recognize the need to support further research in climate processes, global and regional, as mitigation alone is not an adequate strategy

Action: That the Workshop and related planning/processes be an agenda item at the SAEAC-AE meeting on June 8th, St. Hubert. (All Theme and Group Reports comment on aspects of/support this possible Mission). The community will be effectively involved, and engaged appropriately.

4.2 Thanks

As Chair of the "Atmospheric Environment" sub-committee of the Advisory Committee to the CSA on "Solar-Terrestrial and Atmospheric Science", the writer of the background material thanks the Director-General of the SSP, Dr David Kendall, for the opportunity to hold this Workshop. Thanks are also due to Drs. Rejean Michaud (Director of Solar-Terrestrial and Atmospheric Sciences) and Stella Melo (Atmospheric Environment Program Scientist) for their support and assistance. The AE Community is also recognized for their energy and enthusiasm.

The activities of the Atmospheric Environment Community can contribute greatly to the future safety, health and happiness of the people of Canada, through enhanced understanding and knowledge of the Atmosphere and its relation to Climate, and Environmental/Climate Change issues. As such the activities discussed within this report are consistent with goals of the CSA:

"The CSA is committed to leading the development and application of space knowledge for the benefit of Canadians and humanity"

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APPENDIX A

Programmic Themes and Agenda for the CSA's 5th Atmospheric Environment Workshop Banff May 5-7th 2005

A. Preamble:

The Aims of the Workshop are:

1 - To review Canadian progress in the field of Atmospheric Sciences
(0-100km). To examine how the current activities (those funded by the CSA) align with the "Canadian Space Strategy"; and also to compare the overall progress made by the Atmospheric Sciences community with the aspirations of the participants as expressed at the Workshop held in May 2002;

2 - To facilitate communication between the three sub-communities: the scientists, engineers and students primarily engaged with remote sensing from space (space-based), those primarily engaged with ground-based systems, and those mainly engaged with modeling systems;

3 - To look to the future of "space-based" missions, bearing in mind that these should involve collaborations with ground-based systems and with modeling systems: identify priorities, problems and opportunities with the continuation of the enterprise;

4 - To consider how Canadian activities align with global efforts and International Programs in the area of Atmospheric Sciences, and to identify potential contributions. To identify a **Canadian Vision for Atmospheric Sciences for the next "10-years"**;

5 - To afford opportunity for younger researchers (graduate students, post-doctoral) to interact with the wider community and to allow them to help shape the discussions and therefore the future of their research programs.

The Strategy is this:

The Themes for the Workshop of 2005 are a development of the Themes used during the 4th Workshop, which was held at the University of Western Ontario in London (May 2002). The Themes of 2002 provided useful outputs; the summaries and recommendations will demonstrate that we have made significant progress with our research since then. The Summaries from each of those Theme documents will be provided at the beginning of the 2005 Workshop.

The new **Themes** (Section B.) have been chosen to reflect the dominant foci of our activities as a community, some significant developing activities, and the need to meet the "Aims of the Workshop" (above) with appropriate 'products' and documents.

There will first be opportunity, within the Program **Agenda** (Section C.), for the participants involved in each **Theme** to summarize the present status of activity (and relate that to the Summaries from 2002), and to **identify activities**, **opportunities and goals for the next 10 years**. **A written report will be developed (see Agenda).** It is expected that initially participants will identify with the Theme that dominates their research lives.

The above Thematic activity will be followed by the formation of 4-5 **Groups**, each of which will contain members from each Theme. **Each Group's task will be to identify linkages between Themes** (and how to achieve them); and then to **identify overall goals for the next decade.** Subsequent activity will involve sharing of Group summaries, further Group consultations, and a final **Plenary** session for consensus building. **A written report will by formed from these Group summaries (and Plenary), subsequent to the Workshop. The Theme reports will also be suitably revised to reflect the Group activity.**

We stress that although this is a Canadian national program, we expect that there will be extensive International programmic-linkages

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B. Themes for 2005:

* ONE "Arctic Observations"

The 'Northern High Latitudes' Theme of 2002 was clearly timely. Since then the development of **'CANDAC-PEARL'** (Canadian Network for the Detection of Atmospheric Change: Polar Environment Atmospheric Research Laboratory) has involved many of the Canadian ground based community. Topics inherent to PEARL (Eureka) are these: Arctic troposphere, transport and air quality; Arctic radiative forcing; Middle atmosphere chemistry; Waves and coupling processes. However other highly significant initiatives have developed also, some in recent months.

The **'Arctic Observations'** Theme discussions will include the goals and future for CANDAC; the Polar NOAA SEARCH activity; polar satellite 'validation' (e.g. CloudSat/Calipso); and the near-term activities associated with the International Polar and Heliospheric Years (IPY, IHY) of 2007/8.

* TWO "Modelling the Earth's Atmosphere"

The 'Earth System Science' Theme of 2002 explored the dynamical and chemical processes within the Terrestrial atmosphere, and the global coupling processes inherent within any significant regional (Canadian) program. Modelling was a major topic and had a major place in future plans within the summary of that earlier theme. Since then the Canadian General Circulation model (CMAM) has continued to evolve, with increasingly complex coupled chemistry, and an extended version reaching well into the thermosphere. The link with the CSA is now formalized with CMAM-FDAM (Facility for Data Assimilation And Modelling).

The **"Modelling of the Earth's Atmosphere'** theme will include discussions of the opportunities that CMAM-FDAM offers to the entire Canadian community; CMAM goals for the next 10 yrs; the impact of Canadian activity associated with the GEM model (and other models used by the community, such as TIME-GCM); and modelling interactions between scientists associated with the Universities, MSC and the CSA. Data assimilation and "Chemical Weather" are major topics for the present and future.

*THREE 'Remote Sensing (RS) from Space for the Next Decade'.

This is a new but essential Theme for the Workshop, as it is the main area of investments for SAEAC's activities within the CSA's Space Science Program. There have been no workshop opportunities, involving the whole community, to discuss this Theme. There have, however, been many independent International workshops and symposia which have explored the Theme, and Canadians have been prominent in these.

The **'Remote Sensing (RS) from Space for the Next Decade'** theme will explore the role of innovative technologies; the resulting opportunities to 'reach' into atmospheric structures with new measurements; a related consideration of the 'science' of atmospheric regions and how that may require space-based measurements; and a consideration of the role of existing systems now in the CSA program, or clearly identifiable within SAEAC programmic-activity (e.g. SWIFT, EGPM, CloudSat, WaMI, GWIM, HYDROS).

* FOUR 'Environmental Monitoring and Prediction'

'Environmental Monitoring and Prediction' remains at the heart of what is done by the Atmospheric Environment community. It is inherent to the other 3 Themes. It has a strong MSC 'operational' content. The Summary from 2002, and the activities since then, indicate the strength of Canadian activities, but also the ambivalence of government toward funding elements of Environmental 'activity'. '**Climate Change'** has become the 'societal' reason for this Theme's prominence, and at some level the scientist's reason or justification for intensive atmospheric research. 'Climate Change' is now a major theme within Government Departments and Agencies: NRCan, Environment Canada and the CSA are very active.

This theme will explore the Summary and the inherent needs for **'Environmental Monitoring and Prediction'** established in 2002; progress toward those goals; changes in priorities which have emerged 2002-2005; problems with the interface between Government goals/funding, and societal/environmental needs; and the establishment of appropriate goals for the next decade (10 years).

Summary Comments:

The three Themes above (1-3), effectively of research that is focussed around ground-based, space-based and modelling systems, have not been individually discussed by the larger community, and this will happen at Banff. There will also be the essential discussion of *linkages* between them, as a Canadian Vision for Atmospheric Sciences over the next decade is developed.

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C. Agenda

May 5, Thursday

3.00 **Afternoon Tea meeting of Theme Leaders with Alan/Stella**

Part I An overview of the science produced/in production involving CSA support

4:00 **Opening, review of the Agenda (Auditorium)**
Chairing: Alan Manson/ Stella Melo

1 Ground-based systems
4:10: CANDAC (Jim Drummond)
4:20: The Canadian Aerosol Optical Network (e.g. AEROCAN/AERONET and Lidars) (Norman O'Neil)

2 Space-based platforms/missions
4:40: Satellites in operation – OSIRIS, ACE, MOPITT (Réjean Michaud)
5:00: To be launched: CloudSat (validation, aircraft activities) (David Hudak)
5:15: In development: Chinook (Ian McDade)
5:25: Advanced studies (Thomas Piekutowsk)
5:35: Balloon Activities: MANTRA (Kimberly Strong)

3 Modelling systems
5:45: CMAM-FDAM (Saroja Polavarapu)
6:05: GEM-AQ (Jacek Kaminski/Jack McConnell)
6:15: Conclusion

6:30-8:00 – Dinner

4 Post-Dinner Entertainments (Auditorium)
8:00: **CSA Presentation**: "Canadian Space Strategy"; the role of SAEAC; a review of the previous Workshop's Theme Summaries (available in hard-copy form to participants**). Director General David Kendall**
8:20 – 9:00: **Open panel:** What are some of the major issues and scientific questions to be addressed in the next decade? This is to be a free-ranging discussion ----- a warm-up for the Thematic and Group activities of Friday and Saturday. **(This session became a discussion with the DG, and this served the original objectives well.)**
(Choice of Group by Participants)

May 6, Friday

Part II Thematic Activity

8:00 **Breakfast Meeting of Theme Leaders (with Alan and Stella)**
Posters shall be installed at this interval
9:00 – **Plenary: review of the agenda for today (Auditorium)**
9:10 – **Break-out into Theme working-groups (4 rooms)**
(Beverage available 9.30-11.00, at choice of Leader)
Tasks: identify present activity, and relate to 2002; activities, opportunities and goals for the next decade. Prepare for written report.

Theme I: Arctic Observations (Jim Drummond, leader)
Theme II: Modelling the Earth's Atmosphere (Ted Shepherd, leader)
Theme III: Remote Sensing from Space (Ian McDade, leader)
Theme IV: Environmental Monitoring and Prediction (Bruce McArthur, leader)

12:00 – Lunch / Posters may be viewed at this time
Lunch meeting of Group Leaders (with Alan and Stella)

2:00 – **Plenary general discussions: "What we identified for each Theme" (Auditorium)**
2:05 – Theme I: Jim Drummond
2:15 – Theme II: Ted Shepherd
2:25 – Theme III: Ian McDade
2:35 – Theme IV: Bruce McArthur

2:45 – 3.00 Beverage break

Part III Integrated (cross-theme) Activity

3:00 – **Break-out into 5 Groups (Each has people from the different Themes)**.

Group-Leaders: A) William Ward; B) Doug Degenstein; C) Kim Strong; D) Dylan Jones; E) Tom McElroy **(Auditorium, plus 4 Rooms for circa 15 people each)**

Tasks: identify linkages between the Themes, and how to achieve them; identify goals for the next decade.

5:30 – **Plenary: short summary from each Group (Auditorium)**
– Tasks for tomorrow.

6:30 - Dinner

7:30 Informal opportunities for planning and developing collaborations.
Posters may also be viewed at this time.

May 7, Saturday

Part III Contd. Integrated (cross-theme) Activity

8:00 **Breakfast meeting of 5 Group Leaders (with Alan and Stella)**

9:00 – **Plenary: Integration of 5 Group Summaries (Auditorium)**
Tasks: form a consensus of the major features from those Summaries that should be part of the community's "Vision for the Decade" (next 10 years**). NB The Chair provided a Draft of perceived Consensus items; this had occurred so well that a further break-out was not required. There was discussion for an hour.**

Beverage break at 10.15am

10:45 – **Plenary: Putting it all together – next steps (Auditorium)**
Tasks: Present summaries from the Groups again with any revisions: discussion. Consensus Document: discuss the developing Vision inherent in this; implications for the Theme activities; discuss the items as Recommendations and define Actions. Chair to provide strategy to obtain Group Reports and Theme reports, and describe the development of the Workshop Report..

12:20 – **End of the Workshop – Lunch!**

Updated to reflect May 7th changes, on 12th May 2005
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Appendix: Group leaders and assigned members (The total to be 15 or 16)

Group A. William Ward/3 Leader
Ted Shepherd (Theme 2), Jim Whiteway/1, Ted Llewellyn/3, Pierre Gauthier/2, Tobias Kerzenmacher/3 et al.

Group B. Doug Degenstein/3 Leader:
Jim Drummond (Theme1), Godelieve Deblonde/4, Jacek Kaminski/2, Stephen Beagley/2, Svetlana Petelina/3 et al.

Group C. Kim Strong/4 Leader:
Ian McDade (Theme 3), Jack McConnell/4, Saroja Polavarapu/4, Nick Lloyd/3, Tatyana Chshyolkova/1 et al.

Group D. Dylan Jones/2 Leader:
Bruce McArthur (Theme 4), Gordon Shepherd/1, Victor Formichev/2, Marianna Shepherd/3, Tom Piekutowski/3 et al.

Group E. Tom McElroy/3 Leader:
Peter Bernath/3, Charles McLandress/2, Richard Menard/2, Kaley Walker/1, Ben Quine/1 et al.

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APPENDIX B

Remote Sensing from Space

Theme 3 Report

Theme Leader:
Prof Ian McDade

Department of Earth and Space Science & Engineering
Also with
The Graduate Programme in Earth and Space Science and
The Graduate Programme in Physics and Astronomy

York University, Toronto

Introduction and Review of Progress

The large Theme 3 'Remote Sensing' group, made up of mostly graduate students, postdoctoral fellows, research associates, university faculty members, government researchers and industry partners (in order of populous at the meeting), had no need to review progress in CSA activities in Remote Sensing of Earth's Atmospheric Environment from space. This had already been well reviewed in the plenary session of the meeting. This group, of highly active and highly qualified researchers did, however, acknowledge the very impressive contribution that Canada has made over the last decade to Atmospheric Remote Sensing through recent/current experiment/missions such as WINDII, MOPPIT, OSIRIS, ACE-FTS and ACE-MAESTRO. The group also previewed the expectations and scientific potential of future identified experiment/missions such as SWIFT on Chinook and CloudSat.

Overall Strategy for the Future Decade(s)

The group first recognized that the planning for cutting-edge satellite remote sensing experiments, on either 'domestic' or international missions, typically spans much more than one decade. This has important consequences as addressed below under 'Implementation'.

Vision

The group unanimously agreed that '***Improved Atmospheric Science for Improved Human and Canadian Welfare'*** should be the main driver for future remote sensing endeavours. The group also agreed that the required 'science' here, as identified by outstanding/unresolved problems in our understanding of the Atmospheric Environment, must drive the objectives of future satellite missions. The science must then drive the observational objectives which in turn will define the quantities to be measured given available technologies.

In other words:

Human need > Science problem > Atmospheric state parameters to be measured > Desired observable RS quantities > Technology where > means 'defines/drives'

Target Problems to be addressed with Anticipated Future CSA Capabilities and Resources

The group identified the following 3 key '*human need'* problems for future focus:

1. Near-ground level pollution (*i.e*., tropospheric air quality, surface sources of pollution, chemical weather forecasting) – this emphasizes a focus on the ***air we breathe now!***

2. Climate change (trends, carbon cycles, composition & chemistry, global radiation budget) – this emphasizes a focus on the ***air we will likely breathe in the intermediate future!***

3. Atmospheric coupling & dynamics (atmospheric waves, winds, temperatures throughout the middle atmosphere) - this emphasizes a focus on ***the fundamental science we still need to understand in order to properly close on topics 1 & 2 above.***

The group also recognized that there are international-service needs where Canada presently contributes very little. In order to enhance/improve Canada's contribution to the international remote-sensing community, some special thought should be given to developing 'operational follow-ons' to our existing remote sensing instruments

Existing Capabilities and Relation to above Target Science Problems

The group noted that the current experiments/missions currently provide some input on the above science targets:

MOPITT relevant to targets 1 and 2
OSIRIS relevant to targets 2 and 3
ACE-FTS relevant to targets 1, 2 and 3
ACE-MAESTRO relevant to targets 1, 2 and 3
CloudSat relevant to target 2

What do we need to measure from a Remote Sensing perspective?

The atmospheric-state parameters we will need to measure for advancement in each target area are as follows:

Target 1:

CO, SO_2, NO_2, OH, particulates, O_3, organics in the PBL/troposphere

Target 2:

CO_2, CH_4, CO, OH, CFCs, O_3, N_2O, H_2O(gs), aerosols, clouds, precipitation in the troposphere and lower stratosphere

Target 3:

Winds, temperatures, pressure, density, H_2O, clouds, tracers in the stratosphere and lower mesosphere

How will we measure these quantities?

Passive UV/visible/near-IR/IR spectroscopy techniques are our areas of current expertise but we would like to move towards developing expertise in these:

● Microwave capabilities (which will probably be required for tropospheric problems)
● Active techniques

Implementation Recommendations

The group recommended a '*balanced mixture'* of large and small projects with small as potential candidates for the large:

● Small to enhance student training with *hands-on* activity
● Small to allow riskier innovative activity
● Small to allow for better continuity

● Large should preferably be Canadian-led science missions with Canadian instruments and guest international.
● Large (plan B) would be big Canadian experiments on international projects.
● Large (plan B) should **not** be Canadian-provided components on international missions with limited or no clear Canadian scientific involvement.

● The 'small' should allow for testing/deployment on balloons, aircraft and small rockets.

APPENDIX C

Ground-Based (Arctic) Measurements

Prof James R. Drummond, Leader
University of Toronto
May 2005

Introduction

This theme is concerned with the non space-based measurements that support the space-based measurements of the agency. These can be ground-based, aircraft, balloon, etc.

In addition to measurements in direct validation of satellite experiments there are also measurements that can assist with the understanding of satellite measurements and measurements that provide data that satellite cannot obtain, but which are important to improve the utility of those measurements.

Since Canada owns approximately 30% of the Arctic land mass, there is a considerable interest in measurements in the Arctic. In an international context, contributions by Canada to international programs often include a specific Arctic component and therefore there is an emphasis on this area.

Review of Progress

Progress in these measurements has been considerable in the last five years. With the establishment of the Canadian Network for the Detection of Atmospheric Change (CANDAC) and its measurement site at Eureka (80N, 86W) - the Polar Atmospheric Environment Research Laboratory (PEARL) - a considerable improvement in the situation can be expected. It is noted that the CANDAC group have been able to secure considerable ($>7M) non-CSA funding to pursue this objective. It should also be recognized that a number of other groups, such as the Canadian Aerosol Optical Network (AEROCAN), are also installing networks and upgrading facilities with non-CSA funding. Thus the overall position with respect to these facilities is improving.

It is worth noting that the PEARL site is unique in providing a very high number of validation opportunities for polar orbiting sun synchronous satellites, such as the "A-train". Due to a fortuitous combination of site latitude and the inclination of the satellite orbit, the site has approximately the maximal number of overpasses per unit time of any site on the planet. Since overpass co-incidence is a large issue in validation exercises, this is a particularly important and welcome feature.

Collaboration

It is important for all groups to collaborate, but particularly for the ground-based measurement group since there are so many opportunities for expanding the scope of measurements by such activities. Therefore collaboration with other groups, networks and facilities, international and national is an important step that is already being undertaken, but must be further emphasized in the future. In addition to collaboration with data providers, collaborations with data users such as the modeling community and "non-traditional" groups, e.g. health researchers are important. Evidently collaboration with government departments such as Environment Canada who act as both data producers and data users is essential.

Sub-Themes

For reasons of practicality, the theme research can be divided into three major sub-themes:

Air quality – the study of local, regional and global atmospheric composition at low altitudes with an emphasis on the interactions with the biosphere and with humanity. This is often abbreviated to "pollution studies" but in fact encompasses a broader range of issued concerning how the lower atmosphere chemistry proceeds.

Ozone – is a very important gas to study for two distinct reasons. In the stratosphere it is the gas that absorbs ultraviolet radiation which therefore does not penetrate to the lower atmosphere, and in the troposphere it acts as a contributor to the chemistry referred to above in the air quality sub-theme. It is also a minor greenhouse gas.

Climate Change – Is a topic of great social and political interest and requires extremely long-term measurements of great quality. It is the slowest of the phenomena mentioned in these sub-themes, but may ultimately have the greatest effect.

These themes would appear to be enduring, at least for the next decade, and therefore are an appropriate grouping. It should also be noted that there are two other considerations which are implicit in the themes above, but which deserve explicit mention: The issue of understanding the atmospheric circulation, particularly at upper altitudes, and the issue of the water cycle.

Recognising that the entire water cycle involves disciplines that are not represented in the atmospheric community, it is nonetheless important to ensure that the appropriate contributions are made. Therefore the study of the water cycle and evaporation, vapour transport, condensation and precipitation, including clouds and all the physics associated with clouds, should be a part of this theme in support of the corresponding space segment.

Anchor Points

Ground-based measurements at well-controlled and maintained sites constitute "anchor points" which the space segment ties together (and if we want to complete the analogy modeling provides the threads to do the tying!) to provide a complete picture of the atmosphere.

Both space and ground systems sample the atmosphere, but with radically different sampling regimes. Thus ground-based systems provide not only measurement points but can aid with "carrying over" measurement series between satellites and in filling gaps in the timeline of satellite coverage.

A number of anchor points spread throughout Canada are required. These should have a “core” group of instruments. They should not duplicate other networks and sites. PEARL is a site in the high Arctic, and sites in the low Arctic, central, East and West Canada would seem reasonable. A large number of sites is not feasible from both a financial and personnel point of view. Automation of the sites, as far as is possible, should be a goal.

In addition to the fixed anchor sites a “mobile anchor site” - an aircraft - would be desirable for direct in situ measurements at a range of altitudes and to fill in between the fixed anchor points at (temporarily) higher spatial resolution.

Anchor sites should provide a continuous, quality-controlled, archived set of measurements for current satellite measurements and for the future. Validation of satellite measurements is only possible if one set of measurements is trusted and the investment in anchor sites should be aimed at providing the expertise to ensure that the anchor site measurements are trusted.

Relationship to Upcoming Missions

Consideration of the ground-based measurements should be made early in the cycle of a space asset. The requirements for ground-based measurements should be compared to the capability of the anchor sites and if there are deficiencies then new equipment should be proposed, funded, installed and operated well before launch.
This will not be a “cost” to the program – it is an investment in the program success.

Pre-launch measurements at the anchor sites will provide valuable “proto-data” in advance of launch and in some circumstances will permit algorithm development and testing at a higher level pre-launch than would be otherwise possible. Problems and new ideas may also be uncovered which will decrease the issues with the space asset and improve the probability of mission success. It is also an ideal opportunity to provide training and student projects in support of the space program.

One specific example of a deficiency that can be given is as follows: Currently (mid-2005) our PEARL site has little stratospheric wind measurement capability. If SWIFT/Chinook proceeds to launch, then we need to install that capability at least at the PEARL site and hopefully at other anchor sites as they can be activated.

Conclusions

There is a great deal of positive activity which can be used in support of space experiments. The next few years will be a time of consolidation and activation of systems currently being implemented, and this will further improve the situation. The challenge is to continue the upward trajectory by acquiring the resources for the additional anchor points and measurement capability discussed above.

Recommendations:

4) That the CSA support the installation of a small number of “anchor sites” to provide additional scientific information in support of space experiments.

5) That the CSA consider the issue of required ground-based assets for a space project at an early stage in the planning to permit sufficient time for the definition, installation, activation and data analysis from such assets before the space segment is launched.

6) That the CSA continue to support the efforts of the community to acquire ground-based assets in support of atmospheric science through such mechanisms as CANDAC and similar networks.

APPENDIX D

Theme Discussion on “Modelling the Earth’s Atmosphere”

Leader and Chair: Professor Theodore (Ted) Shepherd, University of Toronto

CSA AE Workshop, Banff, AB, 5–7 May 2005

Background: Models are the basis for environmental prediction.[1] In Canada we have two streams of modelling activities. One focuses on climate, is supported by the Climate Research Branch of MSC, and is the basis for the Canadian Middle Atmosphere Model (CMAM). The other focuses on weather forecasting, is supported by the Meteorological Research Branch of MSC, and mainly uses the GEM suite of models. Both involve modelling of chemical species. From the point of view of CSA AE interests, the two modelling streams are highly complementary. CMAM has relatively low spatial resolution but a high lid, and therefore a middle atmosphere climate emphasis. GEM has high spatial resolution, and is thus ideally suited to a tropospheric severe weather and chemical weather emphasis. There is some overlap of interest in the stratosphere, but the use of two independent models in this region, given the large biases in both models and measurements, is very insightful. The two modelling streams use a common infrastructure for data assimilation.

Where have we come since May 2002? Since the last AE workshop, there has been a significant development of the MSC assimilation system. In 2005, 4D-Var has been introduced in the global assimilation cycle of the Canadian Meteorological Centre (CMC), while an ensemble Kalman Filter has been introduced in the Ensemble prediction system. This is a unique opportunity in Canada to have state-of-the-art assimilation systems at our disposal. There are plentiful new observations from research satellites, mainly of chemical species. At the same time, and driven by these new observations, there has been development of a chemical data assimilation capability in Canada. On the CMAM side, the CMAM Facility for Data Assimilation and Modelling (CMAM-FDAM) has been established, and there has been widespread comparison of CMAM with Canadian measurements in the middle atmosphere. On the GEM side, there has been CFCAS funding of MAQNet and the award of an ESA contract, as well as improvements in the GEM suite of models. Important for tropospheric applications is the development of surface modelling and assimilation.

How can modelling contribute to the future plans of the CSA? Modelling (and data assimilation) is the integrator of measurements. It allows one to estimate observation and representative-ness errors, help in the monitoring of observations and calibration of instruments, provide value-added products by merging different data types, validate data, and provide scientific interpretation of data. In this respect, ground-based data is very important for bias correction. At

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[1] Note that for brevity, here the term “models” generally refers to both simulation models and data assimilation systems.

the same time, comparison with (and assimilation of) measurements improves the models, which leads to improved understanding of the atmosphere and an improved predictive capability. Modelling also aids in the assessment of measurement feasibility and requirements for new instruments.

How do we best exploit and enhance CMAM-FDAM? While the MSC is committed to supporting and maintaining the regular version of CMAM, we need to find a “home” for the vertically extended CMAM which is needed for solar variability and MLT studies. At some point in the future, the vertically extended CMAM might be coupled to a thermospheric model. The CMAM-FDAM requires computational resources beyond those that can be provided by MSC. It is important to ensure regular interaction with the measurement community, which involves ensuring easy access to CMAM and CMAM-DA data sets. At the same time, to optimize the leveraging from this activity it is essential to ensure complementarity with MSC infrastructure. In order to fully utilize the CMAM-DA capability, forward models for new data types must be available. Finally, it is important to eliminate outstanding biases in CMAM, notably its ability to represent the QBO.

How do we best exploit and enhance GEM? It is necessary to develop connections with the user community for the global model. This involves ensuring easy access to CMC analyses and observations. The high resolution of GEM needs to be exploited through severe weather and chemical weather applications. This requires an extension of 4D-Var for application to tropospheric source/sink problems. It would also be valuable to improve linkages with the CMAM scientific community (the linkages on the data assimilation side already exist).

How about other models? Canadians should participate in modelling inter-comparison projects, e.g. NASA GMI. Such activities enhance the development of joint tools.

How do we tie modelling more strongly to MOPITT, OSIRIS, ACE, CloudSat, and CANDAC? Current funding mechanisms to achieve this are not optimal, as the various activities are usually funded separately. We need to develop collaboration with other space agencies for Cal/Val at PEARL in the context of data assimilation. This requires forward models and instrument error characterization. For CloudSat, there is a need to enhance linkages with NWP (Meteorological Research Branch) and GCM (CCCma) modellers. The use of cloud-resolving models will be important here.

How do we tie modelling more strongly to non-Canadian missions? We need to develop a mechanism for funding Canadian participation in non-Canadian missions. Even though Canada contributes very little to support directly operational satellites, its research effort in the use of satellite data is well recognized and appreciated by the international community. It is then important that CSA supports the participation of Canadian scientists to non-Canadian missions. The unique location of PEARL would make it ideal to deploy a host of ground-based instruments to help monitor a wide range of satellite instruments. This could be a highly valued Canadian contribution to the support of non-Canadian research and operational satellites.

How will modelling support Chinook? Winds are an important observation type that is currently missing in the stratosphere. SWIFT on Chinook would complement ADM (if launched soon enough), as the measurements would overlap in the 20-30 km range. (However ADM will only measure line-of-sight winds, whereas SWIFT will measure vector winds.) CMAM-DA and GEM are extremely well positioned to assimilate SWIFT measurements. This will provide an essential part of validation. We must ensure a high level of integration with modelling within the science team, in order to establish the mission requirements. We should explore the potential for use of Chinook data in operational forecasts (if available in near-real time); high quality data will have high visibility internationally. For example, it would be appropriate to invest at a very early stage a minimal support to promote research on the use of stratospheric winds in data assimilation with 4D-Var. This would ensure that Canada is well prepared to use the data soon after launch with methods that compare to those widely used in operational NWP centres. An expected science product of SWIFT winds is to help explain why models have difficulties representing the QBO. Comparing the results obtained with CMAM-DA to those of GEM-4DVAR should help contribute to our understanding of the impact of differences in assimilation and modelling approaches.

How to get modelling in at the outset in new missions (e.g. CO_2)? Make it a requirement!
What lies ahead internationally for modelling? More and more data from instruments with increasing resolution (horizontal and vertical); Higher model lids; A focus on improving the water cycle and cloud representation — considered to be the most important uncertainty in climate and NWP models; Coupled earth-system models (e.g. GEMS in Europe), including oceans, chemistry, and the land surface; Ensemble forecasting which will bring a focus on accurately forecasting the variability of the atmosphere; Enhanced spatial resolution to 25 km for global models and to 1 km for limited-area mesoscale models; Stochastic parameterization.

APPENDIX E

Report on the Theme
Monitoring and Prediction

Dr. Bruce McArthur, MSC

CSA's 5th Atmospheric Environment Workshop
Banff May 5-7th 2005

The Monitoring and Prediction Theme discussion was centred around the need for space-based and surface remote sensing observations over relatively long time-scales and large geographic areas related to the long-term goals of increasing our understanding of the changes that are occurring in the atmosphere (Climate Change) and more accurately forecasting first weather, and then a plethora of other environmental factors.

The topic of Climate Change is normally thought to be related to anthropogenic, rather than natural forces, this has little bearing on the physics and chemistry of the atmosphere, but is significant with respect to how governments' view the importance of the climate change issue. Similarly, most think of forecasts as being whether or not the predicted temperature for the day is accurate, while in terms of a long-term plan, the types of forecast expand from weather to air quality and beyond to the prediction of water quality and health. Monitoring for these purposes has historically been of more interest to governments than the academic community, which has had more of an interest in using them than carrying on monitoring programs per se. This difference in interest was evident in both the overall size of the discussion group (7 plus the leader) and the areas from where those participants originated (2 from industry, 2 from MSC and 3 from universities). Those attending from the university community were more interested in the use of the data than its collection, while those from MSC were split between its use (assimilation into operational forecast models) and issues directly related to the monitoring. The two industry representatives were from companies with a significant amount of experience in the development of instrumentation used aboard satellites, but the overall size and scope of the two companies differed significantly; one being multi-national, the other being part of the industrial complex developed because of the emergence of the Canadian Space Agency.

The discussions within the group revolved around two major topics: Canada in space, and monitoring activities at the surface. These discussions, based upon information forwarded from the last forum on Monitoring and Prediction held in 2002, were of a very similar nature to the past discussions. In many respects, the monitoring and prediction community has not moved forward a great deal over the last 3 plus years. Table 1 provides a synopsis of these similarities.

2002 Meeting	2005 Meeting
Security of access to meteorological data. What can Canada do to contribute to the global database? Canada is capable of developing scientific instruments, but has not moved into systematic monitoring (operational). The community notes that interactions are even more important than ever with the remote sensing and upper atmosphere community.	Canada continues to use data from other nations' satellites, but is not contributing to the overall global observational database. There is no method of moving from experimental satellite to operational (e.g., small-sat moving toward operational) satellites. There is an apparent disconnect between the university research community and MSC needs for the data from various satellites (e.g., desirability of real-time data vs. scientific analyses of data over time)

The perceived need for Canada to develop operational satellites for monitoring activities was shared by both industry and government representatives, although for different reasons. In this context, an operational satellite is considered operational based on its design lifetime and the forward planning that such instrumentation would be in service through a number of missions.

The industrial partners associated with the development of science instruments for CSA stated that until projects move from the science stage of being 'one-off' instruments to the operational stage where several instruments could be developed and possibly marketed to foreign space agencies, the industry would not be able to develop and maintain the technical capacity required to be globally competitive. The type of instruments presently being developed through the efforts of the Space Agency, while scientifically sound, were not being developed beyond the prototype stage in that improvements based upon the results of science missions were never incorporated into new missions.

Within the assimilation and monitoring communities the need for on-going monitoring missions was also of concern. The theme group noted that while the science satellites provided potentially beneficial observations, the inability to obtain these observations in real-time limited there use to after-the-fact analyses of atmospheric chemistry and dynamics. The ability to obtain the data in real-time would have real benefit in developing new and better assimilation schemes and thus, provide information that would aid in determining the best types of observational platforms for future missions.

Following these discussions the theme group explored some of the issues associated with why science satellites had not been effectively used in real-time operations. The major reasons brought forth were:

1. That science satellite missions have historically not been well supported following the launch of the instrument. The CSA mandate is in the development and launching of these instruments and to a certain extent in obtaining the data from the platform once in orbit. The data collection, archival and analyses are the responsibility of the science team associated with the individual instruments. Overall, the theme noted that there is a lack of funding to support this analyses part of the overall project. Funding agencies such as NSERC do not have the flexibility to provide funds based on the ever-changing timeline of satellite missions. Often science teams receive a significant portion of their funding before the mission is launched because of delays. Even when the timing of research funds coincides with launch dates, the amount of funding is seldom enough to develop the research and archival team necessary to provide the products in a timely manner.
2. Those in the development of the satellite missions, all possible users of the data have not been informed, or have not acted upon information, about the type of data that would be available from the mission. Two examples of this are the lack of use of MOPITT data by the MSC because of MSC's inability to utilize the data at the time of the launch of the instrument, and the newly announced small-sat program CHINOOK that will produce data on upper level winds and atmospheric moisture content, but will not be able to provide data in near real time (following this meeting, MSC and CSA will begin discussing the possibility of rectifying this situation).
3. That various instruments aboard satellites have not been beneficial for users other than the small science community associated with the launch of the data. The theme group recognized that not all observations will meet the needs of all users. However, it was noted that with limited funding opportunities within the Canadian Space Science sector, mission selection should be based on providing the best science for the overall good of the community. Therefore, it is imperative that the entire community be well informed in a timely manner of possible missions so that each mission can be optimized in terms of its effectiveness.
4. In parallel with (3), the industry representatives indicated their belief that the development of satellite instruments should be science-driven and not industry driven. This comment follows from the CSA Space Technology practice of publishing AO's to the industry for the development of science satellites. Industry felt that this forced them to develop science instruments and find science partners to move an instrument forward. This methodology forced individual industries to develop instruments based on the technology at which they excelled and then find science partners to help 'sell' the instrument to the Agency. Industry prefers that science be paramount and that they become involved once the science is established and recognized as appropriate by the Agency. This would ensure that the science is needed and that the technology required to obtain the science is appropriate.

Because of time limitations, the team briefly discussed the need for surface observations and long-term monitoring. The theme unanimously agreed that surface observations are essential for long-term monitoring and that those that provide vertical profiles of the atmosphere are especially important. The theme expressed concern that such observations have been considered less important recently with the increasing use of satellite data. While it is obvious that satellites provide excellent coverage both in time and space, the theme noted that surface-based observations provided:

1. A means of validating satellite observations and 'pinning' those observations to know well-fixed values of the quantity being observed. The theme noted that while CSA has provided funding for validation exercises for Canadian instruments, that is should also provide funding for the validation of satellite instruments from which Canadian researchers and operational users require data. As Canada does not have any operational satellites, the theme noted that the validation of foreign instruments that are used by Canadians provides a means of 'giving back' to the community that presently sees Canada as only a 'taker'.
2. A method of bridging between various satellite instruments so that long-term trends could be maintained.
3. A means of obtaining high resolution vertical data near the surface where satellite observations are severely limited or non-existent. The one area where surface-based observations are of particular importance to the assimilation community is near-surface vertical wind profiles.

The theme group also noted that modeling, especially when assimilating either surface or space-based observations, was an effective tool for quality assuring individual sites within monitoring networks. This type of quality assurance is used in some UV / ozone validation network validations, but has not yet been used as effectively as it should.

The final major topic considered by the theme was the question of data archival and analyses. There is an absolute need for the free and ready access of all satellite and surface-based monitoring data. It is only when multiple teams begin to analyse data of this type that the quality of the data will be revealed and new science output. The theme group was dismayed that data from Canadian instruments was not readily available. The theme noted that MOPITT data was only available through the United States and that data for many instruments was housed only at the institution where the instrument was developed. To overcome what was perceived to be a grave limitation in the archival and access to this data, and to further develop the various topics the theme had considered, it was determined that a Centre for Data Analyses be established that would be responsible for the following:

1. the archival of satellite and related surface observations
2. the ongoing analyses and improvement of the above data
3. the free and rapid access of this data to the wider community, including real-time and near real-time access for the assimilation of data into developmental operational forecasts
4. the validation of instruments flown on Canadian and foreign spacecraft that were of importance to Canadian researchers and operational users
5. the development and support of networks associated with monitoring and data assimilation.

The establishment of such a centre would necessarily require the cooperation of several government departments and agencies. At a minimum, the atmospheric observations would require coordination between the Canadian Space Agency and the Meteorological Service. Surface observations associated with the atmosphere would require the inclusion of the Canada Centre for Remote Sensing and possibly other government departments. While it was recognized that the establishment of such a centre, which could be virtual, was a massive undertaking, the theme felt strongly that the ad-hoc manner in which data were now being archived had to be rectified to save observations already made and enhance the effectiveness of Canadian scientific and operational research in the future.

APPENDIX F

Theme Integration Group A

Prof William Ward, Leader
University of New Brunswick
May, 2005

Introduction

We took our task to be identifying linkages between the various themes, determining how the activities, interests and priorities of the various themes could be integrated and achieved and to identifying goals for the next decade. We were also asked to evaluate the quality of the Canadian Space Agency's activity and support of the scientific community over the past few years.

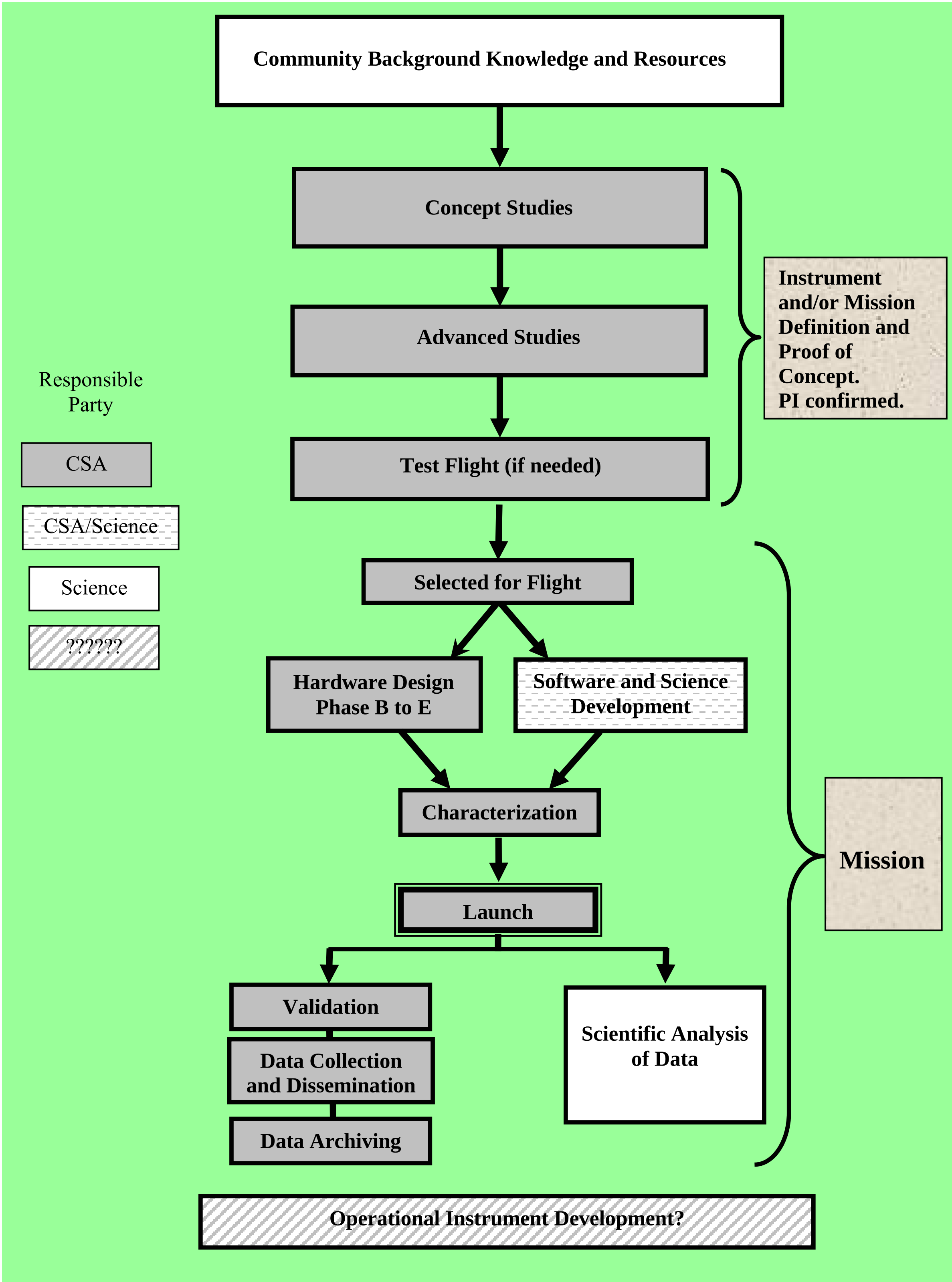
In undertaking this task, we found it valuable to summarize the development cycle of an ideal scientific mission as this clarified where and how activity in the various themes best fit. A schematic of the development cycle follows on the next page. This schematic is not intended to be complete or comprehensive and is best seen as a "strawman" to be augmented or modified as appropriate. It should however provide a suitable context for the comments which follow. Details regarding the schematic are provided in the appendix.

Discussion

It is clear that the activity in space science occurs in a larger context. Ideas for new instruments, assimilation and models do not occur in a vacuum but depend on the prior existence of an appropriate knowledge base within the Canadian community. This is inherent in the university research community and the associated laboratories, in the government laboratories and in the industrial infrastructures and manpower. The Canadian Space Agency is not responsible for the maintenance of this knowledge base although the support it provides these communities for space related activities contributes to its vitality.

It is equally clear that the outcomes of a space science missions have influence outside space sciences both through the scientific knowledge created and through the technologies developed and stimulated during the mission. One significant failing in the Canadian context is the lack of funding and institutional support to capitalize on the considerable investment put into a space science mission by developing related operational instruments and the associated software and data products. The members of the group didn't consider this to be the responsibility of the Canadian Space Agency (although they could be involved). Instead new money should be set aside for this activity. It was noted that in many other countries, these developments are housed in their meteorological service (for example: NOAA or EUMETSAT). Given that instrumentation for observing the middle atmosphere or space weather may be considered operational in the future, it would be wise to consider a broader mandate for the Canadian context.

Concept studies were considered an area where the Canadian Space Agency had performed well. It was noted that an area where capabilities in the Canadian community are currently limited is in the remote sensing of the troposphere. It is recommended that an Announcement of Opportunity for Concept Studies in this area be set up in the near future.



Schematic Diagram of the elements of the development cycle for a Space Science Mission.

It was noted that as our understanding of the atmosphere advances, the role for modelling and assimilation in the development of a mission is changing. It is important to identify what the purpose of a mission is. When new phenomena are being investigated, measurements provide the foundation for modelling and validate the physics being used. At this point the role of modelling and assimilation in the project is relatively minor. As our understanding advances and models become more representative, the role of measurements changes to one of providing “initial” conditions for the modeling/assimilation. At this stage the observation/model/assimilation system is basically operational and modelling/assimilation becomes an essential part of the mission.

An important role for modelling was identified in the software and science stage of the development process as at this point simulations using models provide a means of evaluating and testing the data analysis process being proposed and allow an end-to-end validation of the software with something close to real observations.

Ground based observations were identified as being particularly important for the validation of a mission and the testing of an instrument concept.

Data archiving was identified as an area which needed significant attention. The goal of this activity is to leave a data set and data analysis algorithms in a suitable form for future generations to have access to the data and to reanalyse the data should they choose to. It was felt that this was an area in which CSA should play a significant role.

Entwined throughout the discussion in this group, was the question of where in the mission development process the role of the CSA ends and where the role of an organization such as MSC begins. It was clear that CSA has and is continuing to play a significant role in the development of new instruments and capabilities in Canada. Without new resources, involvement in operational missions is likely to curtail these innovative activities. At the same time unless a means to support these innovations as they mature it can be argued that these innovations are not fully being utilized.

Chinook

It was agreed that stratospheric wind measurements were of great value scientifically and that SWIFT had the potential for being the instrument to provide this data. There was some concern that support of SWIFT could retard the timely development of other instruments and that an effort should be undertaken to engage a larger portion of the community in this project. One way to do this would be to use the available resources on the Chinook to add more instruments to this mission. It appeared that the GPS instrument had not been properly coordinated with efforts by the international community.

Appendix (to be expanded if needed)

The development cycle for a space science mission is divided into two main segments: i) Concept and Principal Investigator (PI) development and ii) Mission. The elements of the cycle have been shaded to identify which areas are primarily supported by CSA.

The Concept and PI development is the process through which concepts are developed, the scientific justification formulated and people with the vision, knowledge and commitment to lead missions identified. While only a small subset of the instrument and mission concepts will be selected for mission funding it is important to maintain activity in this area. It is the main vehicle for bringing new concepts into space science, and assists in the training and maintenance of the highly qualified personnel in the field.

Before an instrument is selected for a satellite mission, a successful end-to-end hardware demonstration of the measurement process should be undertaken. This could take place in any one of the three activity areas in this process although, because of resource limitations, it is unlikely to take place as part of a concept study. For less expensive flight opportunities such as balloon or rocket flights this recommendation can be relaxed.

The "Mission" segment includes full missions, instruments on foreign missions, instruments on small satellites or micro-satellites, balloon flights and rocket flights. It includes the standard engineering development cycle and science activities necessary for a successful mission.

APPENDIX G

Group B Report May 2005
Prof Doug Degenstein, Leader, University of Saskatchewan

Introduction

Group number two was made up of a good mix of individuals representing each of the four workshop themes. The discussion was focused on the maximization of the return from existing and future projects and what role we hoped the Canadian Space Agency would play within this process. We did not focus on linkages between themes but the group members were reminded that this was an important issue. Group two had in depth discussions on five man topics. These included: archiving of data; climate change; public awareness; Chinook; and data usage.

1. Archiving and access to data

The need to effectively archive data was considered a very important issue. The group discussed the merits of full archival of all satellite, ground-based and other data sets. The extraordinary cost of such an endeavour was recognized especially in light of the fact that algorithms as well as data products were required to ensure the data was as useful 40 years into the future as it is now. It was also recognized that the major costs were for personnel. In the end the group decided that we would ask the Agency to help establish a data archival facility to be used only for satellite program data. This facility would necessarily exist with the proper balance between cost and effectiveness.

2. Climate change

The group identified the issue of climate change as one of "BIG Science". It is an issue of global concern that requires long term observations. It was also noted that the Canadian concern is primarily in the Arctic. This issue was definitely identified as one that required input from all of the workshop themes. The group discussed how ground based instrumentation provided the anchor points for satellite measurements and how the models could be used to tie the anchor points and the satellite measurements together. On this issue there are no requests of the Agency but it was identified to effectively study climate change in Canada a coordinated effort from all the themes is required.

3. Public awareness

This issue was considered very important by the group. It was recognized that the Canadian tax payer carries the funding burden for most of the activities performed by everyone in the room. It was also recognized that the tax payer would be more forthcoming if they could identify with the issues under investigation and understood that they were important issues for all Canadians. We identified the need to educate the young people of Canada, especially grade school students, so we will continue to have a stream of new talent knocking on our door. The group discussed the reluctance of scientists to discuss their work with the media yet it was understood that publicity was too important to be ignored. A requirement that a certain fraction of the budget for any CSA project be spent on public awareness was introduced. In the end our group put forward a request to the Agency to help us educate the public and make them aware of the important scientific issues that we study. This aid would not come only in the form of dollars but would consist of training and ongoing support.

4. Chinook and the continuation of Agency activities

The Chinook mission and its impact on the direction of Agency activities was discussed. It was noted that 25 to 30 Canadians now have an active interest in the Chinook project and this number is likely to grow. It was also identified that Chinook would have a major impact on the direction of Agency activities especially with respect to medium or big scale project over the next five to ten years. The group discussed the merits of having one big community wide project with a number of smaller projects that include concept studies, advanced studies as well as actual balloon or rocket campaigns. The result of this discussion was a request to the Agency to maintain smaller programs especially balloon or rocket based instrumentation to provide a training ground for the next generation of Highly Qualified Personnel.

5. Scientific analysis of satellite data

The group also discussed the scientific analysis of data sets produced by Agency projects. It was recognized that a request for funding from the Agency for such activities was not appropriate. However, it was also lamented that the funding always expires at the exact moment the data becomes useful. The group identified this as an issue of coordination between the Agency and other agencies like NSERC and CFCAS that have a mandate to fund the scientific analysis. This discussion resulted in a request to the Agency to help us find some way of better coordinating the major funding agencies.

Summary

The group decided on four requests of the Canadian Space Agency. We would like to ask the agency to help us archive the data produced by Agency led satellite missions, we would like the agency to help us get our message out to the public, we would like the agency to continue to provide a training ground for the next generation of scientists and we would like to ask the Agency to continue to do everything they can to coordinate all the funding agencies required to make a successful climate change mission.

APPENDIX H

Report from Group C

Provided by Prof Kimberly Strong, Leader
University of Toronto

Summary of the Group Meeting – Friday Afternoon

The meeting began with a brief review of our tasks for the Group meeting:
1. To identify linkages between the four Themes
2. To discuss how we achieve these linkages
3. To identify goals for 2005-2015
4. To provide feedback and identify any weaknesses and strengths in the themes

We then reviewed the scientific questions that need to be addressed in the next decade, which effectively represent science linkages between the themes. We agreed with the issues that had been identified during the Theme presentations:
- Pollution and air quality
- Climate
- Ozone – some discussion of whether this included tropospheric ozone, as well as the issue of stratospheric ozone depletion
- Atmospheric circulation – waves and coupling
- Water – this topic could extend from the planetary boundary layer to the mesosphere

The question of the level of coverage was raised – what spatial and temporal coverage is required of a satellite mission? For example, should we be launching two or three of the same satellite to ensure sufficiently dense coverage. The continuous coverage offered by satellites in geostationary orbit was noted – we should be thinking about the possibilities of GEO. The question of whether we could usefully deploy remote sensing science instrumentation on the ISS was also raised – orbit would limit high latitude coverage.

We reviewed the concept of developing a suite of stations that would comprise a "ground-based satellite", each having a suite of core instruments. This is consistent with the intent of CANDAC. These sites would be distributed in latitude and longitude bands across Canada to do space science from the ground. Where does space begin? Below 100 km? A tentative suite of instruments was identified in Arctic/Ground-Based Theme, consisting of (i) meteorology instrumentation for temperature, humidity, winds, radiation, (ii) lidar for ozone and temperature, (iii) Fourier transform infrared spectrometer for constituents, and (iv) microwave radar for clouds and precipitation. Additional instruments would be added as appropriate, given resources, capabilities, and validation needs. This ground-based network would provide validation, process studies, continuity, bias-correction to DA, independent science, and high temporal resolution. It was noted that trajectory modelling can be used to derive 3D information from a point measurement, thereby effectively extending the spatial coverage. Stand-alone science would be done at these sites, and they would continue operation during any gaps between space missions. In addition, it was noted that both models and satellite datasets have inherent biases. Ground-based measurements can provide independent data that are useful for correcting such biases for data assimilation purposes.

A complete space mission should include the budget and resources for:

- The satellite instrument
- A ground-based component for (i) validation from well-calibrated and well-understood instruments, (ii) complementary measurements, (iii) stand-alone science between missions
- A modelling component

The importance of ensuring sufficient funding and people to fully exploit the data was emphasized. It was suggested that we look to the international community (e.g., India, China) to address the shortage of personnel, both through including international partners on science teams and bringing people to Canada for training and integration into projects. Can nano-satellites provide useful training?

On the issue of operational satellites, there was a concern about the high costs imposed by the requirements for reliability and real-time data processing. A multi-agency approach is needed if Canada is to get involved in operational missions. However, it was noted that such missions are not part of CSA's mandate, although there is a certain moral obligation on Canada/MSC to our international partners. A data office would be essential for an operational mission.

Discussion of possible recommendations:

- Support for a central data centre, jointly run by CSA and MSC. NSERC may also be interested, in the context of the NRC/CIHR/NSERC/CFI National Consultation on Access to Scientific Research Data currently underway to review the issues surrounding archiving of scientific data in Canada. Quality control will be very important in this context.
- Access to aircraft. This included both (i) science flights, including the possibility of installing instrumentation on commercial aircraft (e.g., a chemical package for upper troposphere / lower stratosphere and air quality studies), and (ii) testing and validation of space instruments. Possibly make such testing standard prior to launch of a satellite instrument.
- Small missions are important: balloons, aircraft, and rockets. These help to provide continuity to the science community.

Modelling linkages:
Process studies are key. Measurements provide information on atmospheric processes. This new science can then be incorporated into models to improve their representation of the atmosphere. It was noted that although most of the discussion in the Modelling Theme had been on 3D models, useful insights can still be gained from "limited" models such as box and 1D models. While measurements provide input for models, models can also provide input to measurements, for example, a priori profiles. To maximize the usefulness of model fields and results, they must be easily accessible to the community. It was recognized that there are

funding limitations on modelling activities. Proposals for space missions need to include resources to ensure model readiness at launch, not several years later.

We also discussed the synergy between Canadian space missions and the resulting data with the global dataset. There is an issue of how to most effectively use all the data available. This is also relevant to data assimilation, where data from many different instruments may be used. It was suggested that a person is needed to survey the possibilities here – to determine what global datasets are available and how can we combine them with Canadian data. Permanent funding of a person or people at a data centre would help here – somebody who is an expert in data retrieval.

Our group clearly saw the complementarity of

- ground-based measurements
- balloon/aircraft/rocket measurements
- satellite missions
- models - CMAM and GEM, but also "more limited" models

Wish List / Goals for Next Decade

- A big(gish) satellite mission every five years
  → the value of Chinook was recognized but there was concern over details of budget implications
  → not at the expense of everything else – how much funding is left if Chinook flies?
- Support for small missions – balloon, aircraft, rockets
  → essential for small science, instrument development, training of HQP
  → especially essential if Chinook goes ahead and support for other satellite missions disappears
- Support for data centre + people to facilitate interactions between measurements, models, other data
- Integrate modelling component into missions from the start
  → to maximize return on investment in satellite missions
  → need sufficient lead time to be ready to use the data at launch
- Support for suite of "ground-based satellite" stations, each having a suite of core instruments
  → to provide validation, process studies, continuity, bias correction to DA, independent science, high temporal resolution, trajectory modelling to derive 3D information
- Integrate ground-based validation into missions, with deployment well before launch, including instrumentation where needed (e.g., wind instruments for SWIFT)
- Aircraft validation where appropriate – access to aircraft is needed
- Start investigating microwave technology
- Lidar and other instrument technology testing on balloon/aircraft for space applications
- Need to collaborate more with the international community

A number of recommendations were presented after the plenary discussion on Saturday morning:

- Continuing AOs for concept studies, advanced studies – these programs work well
- Continue Small Payloads Program for balloons, aircraft, rockets, and micro-satellites
  → issue of quality of science vs. instrument development and training

→ have two options for proposal review path depending on the emphasis?

→ these will be especially critical if the space missions in the atmospheric environment community are limited to Chinook and possibly one other mission in the next decade

- Support of people

  → can CSA fund its own postgraduate scholarship program? The top-ups of the NSERC PGS are welcomed, but many excellent students in our community do not get these but are still deserving of scholarship support – recognition of this by the award of a CSA scholarship is recommended

  → career issues for those at PDF/RA level – in subsequent discussion, several possibilities were raised such as establishing an institute analogous to the Institute for Particle Physics, proposing a new theme to the Canadian Institute for Advanced Research, and lobbying with our universities
- Climate change mission – should include issues of GHG sources/sinks, pollution, air quality, not just CO_2 monitoring
- The AE community must devise cohesive approach to deal with multi-agency funding issues

APPENDIX I

Group D Summary

Prof Dylan Jones, Leader
University of Toronto

In each theme it was recognized that climate change and air quality will continue to be of great concern to Canadians for years to come and that the CSA can play in important role in addressing these issues. In particular, enhancing our ability to predict the impact of anthropogenic emissions on air quality and to quantify the influence of intercontinental transport of pollution on Canadian air quality are especially relevant goals for the CSA as assessing the intercontinental transport of pollution is best done from space. The CSA's activities can also contribute significantly to improving our understanding of regional climate change, with particular emphasis on the impact of climate change on Canadian air quality and the water cycle.

The CSA can also play an important role in enabling Canada to meet its obligations to international regulatory agreements, such as the Kyoto Accord, through the deployment of a space-based monitoring system. Such as system, although targeted for policy needs, could have significant scientific rewards.

Observational requirements

Achieving these goals will require a broad suite of measurements in both the lower and middle atmosphere. In the lower atmosphere it will be especially important to measure diverse trace constituents such as O_3, NO_2, CO, H_2O, particulates, hydrocarbons such as CH_2O, etc…

To improve our understanding of climate-related issues such as the carbon cycle and to provide better constraints on Canadian air quality, it will be important to recognize the complementarity between ground-based and space-based measurements. Although the ground-based measurements are critical for satellite validation, these data will provide valuable additional information to address these issues. Therefore, in designing new space-based mission, it will be important to assess the new instruments in the context of the total information content available from an integrated surface and space-based dataset.

To accurately predict the impact of human activity on climate will require an improved understanding of the natural variability of the climate system. Current CSA initiatives such as the Chinook mission will provide valuable data in this context. Future missions should aim to extend these measurements, with the goal of providing new information to enable us to better understand the influence of natural variability in the atmosphere on the climate system, from the middle atmosphere down to the surface.

Although these issues of air quality and regional climate change are important for Canadians, we must recognize that currently there exist a number of international satellite missions at NASA and ESA, for example, focused on these issues. Therefore, the CSA must be careful in ensuring that new Canadian initiatives, while meeting Canadian needs, represent a valuable contribution to these international projects.

Modelling requirements

Effectively integrating the different space-based and ground-based measurements will require an extensive data assimilation system. Significant progress has already been made in developing this capability. The existing assimilation system, however, must be extended to provide coupled numerical and chemical weather prediction from the surface to the middle atmosphere. This data assimilation facility would also provide a useful tool for observing system simulation experiments to help guide mission requirements for new satellite instruments.

The current generation of models must be improved to better simulate the natural variability in the climate system, such as the quasi-biannual oscillation (QBO) and the Madden-Julian Oscillation (MJO). Similarly, the models must better predict synoptic variability in the troposphere, such as storm tracks and extreme weather events. This will require, for example, an improved representation of gravity waves in the models as energy transport by gravity waves can have a significant influence on 3-5 day forecasts.

The hydrological cycle in the atmosphere represents an important component of the climate system. It will be essential to enhance Canadian expertise in cloud microphysical modelling to exploit data from current Canadian instruments such as CloudSat, and to help determine future measurement needs in this area.

Data Archive

At present, there is a critical need for a national data archive for both surface and space-based measurements. Such a facility will help make available to the Canadian community the data from CSA and MSC sponsored programs. As the number of instruments deployed by the CSA and MSC increases, this data exchange facility will become more important for the community. Furthermore, a long-term archive will ensure future access to old instrument data, which will be essential for detecting trends in the climate system.

For a central data archive to be successful, an effective search tool must be carefully developed to provide efficient access to the data. In addition, it may be necessary to establish a data management system (similar NASA's, for example) with a timetable for making data publicly available and for archiving the data associated with each mission.

Recommendations

1) The CSA should encourage the development of instruments to provide a broad suite of measurements in the lower and middle atmosphere, with particular emphasis on acquiring new measurements of trace constituents such as O_3, NO_2, CO, H_2O, and particulates in the lower atmosphere.

2) The CSA should recognize the complementarity between ground-based and space-based measurements, and consider integrating the ground-based measurements in the design of space-based missions to enhance the overall likelihood of the missions successfully achieving their scientific objectives.

3) The CSA should strengthen the existing chemical data assimilation capability in Canada, with immediate focus on improving the representation of tropospheric chemistry in Canadian models so that existing and future measurements of tropospheric trace constituents can be exploited fully.

4) The CSA should help establish a national data archive for ground-based and space-based measurements.

5) If a national data archive does become a reality, the CSA should consider establishing a data management system to streamline the delivery of data from each mission to the archive and to ensure that the community will timely access to these data.

APPENDIX J

Group E - Linkages between Themes

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Introduction

Group E was tasked with exploring linkages between the Workshop Themes. The four themes are ‘Arctic Observations’, ‘Modelling the Earth’s Atmosphere’, ‘Remote Sensing (RS) from Space for the Next Decade’ and ‘Environmental Monitoring and Prediction’. After the theme discussions took place several groups were formed to identify linkages between the themes and identify overall goals for the next decade.

Discussion

One of the first linkages identified was the common need for communication an discussion between the people working in the different disciplines and the different theme areas. The close synergy between instrumentation and data assimilation was noted and noted also in the more general area of remote sounding. There was some discussion of the value of measurement ‘case studies’ that serve as fruitful diagnostic opportunities for model validation.

In the discussion, the Arctic theme was carried a representative of the more generalized concept of a ground-based observing system. Its role in providing complementary as well as calibrating input to the satellite observations was noted. The ability to build on the work already done was linked to a need to find follow-on missions for successful space instruments such as ACE and ODIN.

There was some discussion of whether an atmospheric mission might be profiled to provide valuable data relevant to the Kyoto protocol and thereby be interesting to government. Climate change was seen as a linking theme tying the other themes together. There was recognition that a tropical wind mission would have a strong bearing on Climate Change from the Canadian (polar) perspective. This is of course a link to the Arctic observations theme.

The need to use ground-based measurements to fill the gap between space missions was identified, as well as the validation role indicated earlier.

The complementary roles of the MSC and the CSA in this research were identified, particularly with respect to communication to the community and for the management of data.

The problem of retaining highly qualified personnel in order to address complex science issues was recognized as a common problem across all the themes. There was reference to the report that Gordon Shepherd and a few other community members produced concerning the management of projects to maintain a flow of new instruments and science measurement concepts toward launch opportunities. The need to mange the process was recognized.

Recommendations

1. That there be consideration of forming an interagency component to improve communications and data exchange.

2. That a Climate Change science satellite mission be considered as a vehicle for planning the next ten years of atmospheric observation.

3. The CSA continue to support modeling and ground-based observation programs as much as possible as important components of the space-based observing system and as the source for new mission concepts and HQP.

4. Canada should consider having an international role in global and regional climate change monitoring.

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