Report on a Workshop of the Working Group on Atmosphere-Related Research in Canadian Universities

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Over the past year a working group of researchers based in Canadian universities have engaged in a strategic planning activity intended to identify and articulate academic research and education priorities in atmospheric, ocean, climate, and related research in the coming five to seven years. The areas of research thus identified have been tentatively grouped under the name "Atmosphere-Related Research" (ARR). The activity stemmed from discussions about changes in funding and partnerships between university and government researchers. The activity was stimulated and focused by a workshop at McGill University in August 2014, that was hosted by the US University Corporation for Atmospheric Research (UCAR), where new ideas on how to move forward with organizing this Canadian community were considered.

The initial aim of the "Atmospheric Related Research in Canadian Universities" (ARRCU) working group is to produce a short White Paper that will serve as the basis for future strategic planning and organizational activities. (The organizing committee of the ARRCU Working Group are the authors of this report.) On April 23, 2015, a draft version of this White Paper was circulated and on May 8, 2015, a workshop was held to discuss the draft White Paper and other aspects of this initiative. The purpose of this report is to summarize the proceedings of the workshop. Workshop materials, including background documents, slide decks, audio recordings and session summaries are available at http://tinyurl.com/arrcu-may2015-workshop.

Workshop Summary

The May 8 2015 workshop took place at the Hotel Delta Montréal with generous support provided by NSERC (Natural Sciences and Engineering Research Council of Canada), l'Université du Québec à Montréal (UQAM), McGill University, University of Toronto, and Canadian Meteorological and Oceanographic Society (CMOS). Over 60 professionals from Canadian universities, government, and industry participated in the meeting either in person or online. The meeting centered on three panels that reviewed the draft White Paper and discussed issues of community scope, priorities, and partnerships.

In an **Introductory Overview Session**, P. Kushner discussed the background and scope of this initiative and White Paper, as well as comments and feedback received to that point. R. Stull then gave a presentation on the need to shift ARR towards identifying future societal stresses and economic opportunities, to ensure prosperity for Canadians in a changing climate. Finally, J. Drummond provided a view of multiple "dimensions" of ARR research including discovery research for intrinsic scientific interest, commercial applications for prosperity, and societal interest for public and environmental protection.

For **Panel 1: ARRCU Community Scope, Definition, Purpose**, the chair K. Strong reviewed the proposed community scope in the White Paper, discussed connections to Canadian professional societies, and suggested UCAR (University Corporation for Atmospheric Research) as a possible model for ARRCU. The purpose of ARRCU's strategic planning, she proposed, is to identify opportunities and collaborative mechanisms, improve dialog and advocacy for ARR faculty and universities, improve data and infrastructure access, and improve planning in education and vocational training.

In the Panel 1 presentations and discussion, it was proposed that ARRCU's role should not be to organize the community's research in a top-down manner. Instead, our community should have a means to help spur new collaborations between groups that have not previously interacted. The White Paper should define multi-disciplinary research objectives or critical concerns related to partner industry and government strategic goals, such as in the area of water resources, to attract people who may want to fund or participate. Over the short-term, ARRCU could remain focused on follow-on programs to the Climate Change and Atmospheric Research (CCAR) program, with the research capacity of the ARRCU community presented as a compelling "value proposition". In the discussion, it was stated that prioritization is necessary, even if challenging. Over the long-term, something like ARRCU could become an organization to define ARR-related problems, to develop Canada's predictive capability [following the lines of international assessments like the IPCC (Intergovernmental Panel on Climate Change) assessment reports], to identify responses and solutions in the domains of social scientists, economists, and integrated assessment modeling, with a view to policy making and adaptation planning, implementation, and evaluation. A community of researchers like this could be in a good position to respond quickly to changes in climate or to new funding opportunities.

Participants emphasized that a strong linkage of fundamental research to practical societal applications should be a core element of the ARRCU plan. ARR fundamental research ranges from work in an individual investigator's laboratory focused on a specific process, to novel field work, long-term measurements, and satellite retrieval methods exploring new concepts, to theoretical work and mechanistic modeling studies focused on process

understanding and new physical parameterizations. ARR applied research includes forecasting and environmental prediction, and research relevant to human health, agriculture, land and water resource management, climate change adaptation and impact evaluation. The fundamental to applied science linkage is especially critical for broad support of projects requiring large-scale infrastructure such as satellites, field programs, and high performance computing. The potential payoffs of ARR need to be articulated: for example, funding from NSERC, Environment Canada (EC), Health Canada and the use of NASA (National Aeronautics and Space Administration) satellites enabled a study on a Canada-wide assessment of exposure to fine airborne particulates (PM2.5), providing potentially tens of billions of dollars in health benefits. As another example, research on atmospheric chemistry in the Arctic contributed to the understanding of the emergence of the ozone hole which in turn led to an international agreement, the Montréal protocol, to address this very critical societal problem.

Participants suggested that the time scale of research and benefits needs to be carefully balanced. There was a recognition that an excessive focus on short-term needs of specific industries risks losing research of enormous benefit to society, different levels of government, and a wide range of industries.

Participants emphasized the synergistic multidisciplinary nature of ARR. For example, in the area of atmospheric chemistry research, understanding the physics of transport informs the understanding of chemical processes, while knowledge of atmospheric chemistry provides useful dynamical constraints on transport. The scope and definition for the name "atmosphere-related" research needs to be explained carefully, because it can include important research areas such as oceanography, soil science, vegetation, glaciology, forest meteorology, and agriculture meteorology. There were several suggestions for broadening the community, including public health and epidemiology, industrial chemistry, paleoclimate, physical/biological/ecosystems impacts research, and solar-terrestrial physics. Generally, flexibility and avoiding excluding people by setting rigid boundaries was supported. Despite suggestions to broaden the community, there was an overarching sense that the ARRCU White Paper needs to be carefully focused on important science problems that a large portion of the community agrees to be of high priority.

Regarding the Canadian context, it was suggested that this group needs to recognize the Canadian context. It needs to be organized nationally but to recognize provincial leadership in research funding. ARRCU should take advantage of existing professional societies – CMOS, CGU (Canadian Geophysical Union), and the recently formed Canadian Societies for the Geophysical Sciences (CSGS) – for its organizational effort. There was considerable discussion of communications and advocacy for this community during this panel and throughout the workshop. It was recommended that the White Paper have a succinct vision statement and should include a list of grand challenges or key science questions. Communications should be a key purpose of the document and emphasized in the title. Participants pointed out that there is a large and growing media and public interest in our fields of research like weather and climate. There is a need to make people aware of what the ARR community is doing and why it matters, but also to be wary of straying into the political arena and taking on broader organizational issues that are not unique to ARR.

Ideally, the White Paper should adopt a tight communications message: clear, constructive, authoritative, on-message, and focused. Science described in the plan should be based on clear objectives and underscore the value of collaboration between scientists and users, and emphasize partnerships across disciplines. While potential threats arising from naturally occurring severe weather and anthropogenic climate change are important, a question was whether it should be a point of emphasis in our communications. It was also suggested that ARRCU could be recognized as an expertise network, e.g., having a list of experts available to talk to the media.

The case for using ARRCU to advocate within the university community was pointed out: it would be useful to have materials and a group that could advocate to university administrators the case for new faculty hires in ARR, present the relevance of ARR for research and education, and break down internal barriers to interdisciplinary work. The Canadian Consortium of Ocean Research Universities (C-CORU) was raised as a successful example of high-level advocacy within Canadian academia. A related point is that a strategic plan could be used to communicate our needs to Compute Canada and other agencies like CFI (Canada Foundation for Innovation) providing infrastructure for ARR.

For **Panel 2: Priorities in research, education, and training**, Panel Chair P. Gauthier prepared a briefing document (which can be found under the "Background Documents" directory at tinyurl.com/arrcu-may2015-workshop) describing the need for international collaboration required to engage in coordinated model and observational efforts, and the need to identify unique Canadian contributions to global ARR. He also pointed out that there was a need to provide students and other HQP (Highly-Qualified Personnel) a sense of the purpose and socio-economic value of their research. Panel 2 was charged with identifying priorities for our research and education, and what this would imply for our infrastructure needs and classroom approaches.

It was proposed that a natural focus of ARRCU should be on Canada's land mass, its coastal zone, and its Arctic territory. Canada, with limited resources, needs to leverage "niche" areas, e.g. satellite limb sounders like SciSat ACE

(Atmospheric Chemistry Experiment) and OSIRIS (Optical Spectrograph and InfraRed Imaging System), and its significant strength in Arctic and polar science including meteorology, cryosphere science, and cold region hydrology. Because of logistical challenges and a harsh environment, Arctic research is very expensive but necessary to support to continue our leadership in Arctic science. At the same time, the teleconnected nature of weather means that local weather depends on global conditions and we cannot focus exclusively on the Arctic or any other particular region. Research in weather, climate, and air quality in a changing climate thus requires a global perspective, although Canada should emphasize its strengths in certain regions.

Research into climate extremes, process understanding, regional climate, and air quality should be of high priority. To achieve the highest model resolution possible (1-10km scale) relevant to resource management and impact assessment requires fine-scale regional climate models that Canadian universities (through UQAM and the Ouranos consortium) have heavily invested in and worked to characterize and improve. Leveraging such investments are international collaborations – for example, in regional modeling – in which Canada has a well established leadership role. Modeling efforts using internationally available open source tools, such as the National Center for Atmospheric Research's Community Earth System Model and Weather Research and Forecasting Model (CESM and WRF), are also greatly valued within the university community for fundamental research and applications. Despite the growing emphasis on comprehensive models runs on high performance computers, several participants pointed out that simple less expensive models can be used to test ideas and confront model formulations with data, and that fundamental research based on physics, mathematics, and chemistry should be at the forefront of what we do. Insight from models requires a deep understanding of their physical basis and limitations; this has clear implications for our educational mandate.

Participants suggested that field measurements and observational networks (e.g. of wind profilers and carbon dioxide and water vapor flux measurements) should be given high priority. Monitoring over the long term is an ongoing challenge. Traditionally, EC has been responsible for maintaining such networks and universities struggle to maintain such networks for monitoring. Universities have observation stations that collect data, but it is challenging to find funding to pay for the indirect costs and the long-term operational costs. Furthermore, the cost and long timescales of space-based observational systems need to be recognized. Systems currently in place grew out of ideas proposed in the 1980s or 1990s. The path from instrumental research to broader applications is not linear; the best results often face real risk of failure or unanticipated applications [e.g. GPS (Global Positioning Systems) applications in consumer electronics and meteorology].

Integration between universities and governments at a national and international level was seen as being required to be able to deploy observations and do the monitoring of oceans, land and atmosphere on which is based the progress made in modeling. In that respect, the CCAR program has been very helpful in promoting this type of integrated collaboration between different universities and government laboratories. Canada needs to show that it is fully contributing to the global effort in terms of observations and investment in research, and the ARRCU community should make sure to link its strategic planning priorities to several international programs that have developed their own plans over the last several years, rather than starting from scratch.

On education, it was suggested that we should prioritize online courses (following the UCAR COMET model) to take advantage of expertise that is dispersed across different Canadian universities. Academic and industry participants emphasized the need for more practical training in meteorology and oceanography that is directly oriented towards the needs of the commercial sector, for example in areas of air-quality, insurance, etc. Also related to education is the need to develop student intuition using simple models and to make sure that students understand the mathematics, physics, and chemistry upon which comprehensive models are based.

Panel 3: Partnerships, chaired by J. Gyakum, discussed ideas to facilitate research, education, training, and employment initiatives with ARRCU's non-academic partners. The Panel discussed partners' impression of the ARRCU initiative, how to attract suitable partners, and what might be useful in scope and prioritization, in both research and education. J. Gyakum described an "operations to research" model for partnership proposed by UCAR President T. Bogdan. In "operations to research", academics interact with partners in industry and government, and listen to partners' stated needs for research. This concept is the reverse of "research to operations", an example being an operational weather centre benefitting from an academic initiative to incorporate a new numerical, or physical parameterization, into an operational weather forecast model.

E. Boston provided NSERC's perspective that a long-range plan should select activities that have interest to a significant portion of the Atmospheric-Related Research (ARR) community. The planning should recognize that NSERC supports ARR through Discovery Grants, supplements, scholarships, etc., to students and postdoctoral fellows. We should bear in mind and do better in the areas of industrial partnerships, involving hydro-electric companies, water resource management, NSERC Networks of Centres of Excellence, etc., following the example of ArcticNet, MEOPAR (Marine Environmental Observation Prediction and Response Network), and other networks. These partnerships can help create job

opportunities, guide new research directions, and assist companies in building their businesses. There are grants for travel for universities and industries to meet in order to establish collaborations. E. Boston also reminded participants that the CCAR program is midway through its term and would be reviewed in the coming year.

Representing the EC perspective, G. Brunet (Director, Meteorological Research Division) proposed a university-government partnership model like the United Kingdom Meteorological Office's Academic Partnerships, which deals with funding for HQP and selected university faculty. Such a partnership includes meeting regularly to discuss funding distributions to develop strategic funding to take into account weather, climate, and fundamental research. The CCAR model was partially successful but the balance of funding needs to be corrected to ensure funding for weather research reflecting language in the call dealing with weather research themes. A successful funded partnership would provide proper academic partnerships and train HQP according to the needs of the job market. Also speaking to the EC perspective, C. Lin (Director General of the Atmospheric Science and Technology Directorate) stated that government-based laboratories provide the most appropriate basis for the tasks of performing routine networked long-term monitoring, as for air quality. But intensive monitoring (e.g., in the Alberta oil sands) involves multiple partnerships on university and government levels. Satellite data monitoring and research represent excellent opportunities for partnerships at the university and international levels. He suggested ARRCU consider the concept of MOST (Models, Observations, Satellites Together), which involves the integration of observations and satellites via an assimilation network. He also concluded that CCAR to date has delivered what it set out in its mandate. In particular, the desired knowledge transfer to government from universities has been occurring.

M. Fekri (Pelmorex) represented the industry perspective. He stated that a Canadian ARR community would hopefully enable easier engagement between university, government, and industry and allow for an optimal allocation of funding for initiatives that are beneficial to all partners as well as a consistent point of contact between the private sector and academia. Key challenges are: a) Communication: how to enable effective longlasting working relationships, which could be facilitated by having a means through this kind of group of establishing first contact; b) Research Focus: Pelmorex's, and more broadly industry's, primary goal is the application of scientific knowledge to business problems that have discernable public benefit and interest. It needs to be recognized that strong applications stem from strong foundational scientific understanding. A common ground needs to be found to the mutual benefit of both partners.

In written remarks about education and training, C. Scott (Pelmorex Chief Meteorologist) stated that, given the skill of numerical weather forecasting and the need for hyper-local weather information, there will be a need for meteorologists who understand the physics of the atmosphere but can also assess and communicate risk. This requires a well-rounded scientist with a mix of strong analytical, computational, and communication skills. Additionally, a modernization of programming courses should be undertaken from Fortran to languages like Python and Java. Communication and teamwork should also be a focus so that students can learn to articulate the theory and hone skills that may not come naturally.

According to T. Piekutowski of the Canadian Space Agency, the space agency has always been in the business of partnering industry, academic, and government sectors. Costly space-related initiatives must respond to government needs in order to be useful, and often concepts flow from the academic side that industry turns into products used by government partners. Government efforts involve deliberate and safe development, while the academic community tends to propose more risky, yet scientifically ground-breaking, research concepts. In the ARR planning process, it is important to identify shared priorities and for universities to do a better job of quantifying the value of the resources they bring to projects. The CCAR model of insisting on firm commitments from a university-government partnership has been very effective in ensuring that university research is useful to government. Thus far, NSERC grants facilitating industrial/academic collaboration seem to be underused.

A. Bourque of Ouranos described his organization's partnership model: Ouranos is a private, non-profit organization, which consists of a network of approximately 450 scientists and professionals from academia, government, and private industry. The approach involves active participation in partnerships, in which users are involved during each step of the process. The process of asking the right questions and developing the projects, although time consuming, is worthwhile – reflecting an operations to research process. This engagement facilitates the development of a research program that benefits everyone.

W. Perrie (Fisheries and Oceans Canada/DFO) pointed out that DFO's research focus serves departmental mandates such as 'safe and accessible waterways'. Atmosphere-ocean dynamics research supports this mandate through studies of marine storms, air-sea interactions, marine winds, and waves, etc. This research is directly relevant to national societal priorities, like offshore hydrocarbon development, fisheries activities, marine transport, and search and rescue. Presently, projects based on NSERC funding, such as MEOPAR allow funding federal scientists who are also adjuncts at universities, working in partnership with university faculty and HQP in their groups. There are also limited international partnerships such as with the US Office of Naval Research. DFO can in addition support postdoctoral fellows via the NSERC Visiting Fellows

program.

During other discussions related to this Panel, it was pointed out that while some researchers, such as atmospheric chemists, have successful funded collaborations with EC partners, generally NSERC funded partnership programs involving EC and the Canadian Space Agency are difficult to arrange. In particular, climate-related research has been excluded from the NSERC Strategic program. Concern was expressed of barriers to collaboration with EC and government, including the difficulty in gaining access to government domain data. It was also suggested that the Canadian Space Agency and EC work together to help build opportunistic collaborations with universities; in response, it was stated that steps are being taken to increase the collaboration between these two government agencies. Regarding long-term monitoring, it was pointed out that universities may need to fill in gaps left by monitoring programs cut at the federal level, and that long-term monitoring on individual sites or for small regions can justifiably be carried out by university-based researchers. Finally, a missing element in the partnership discussions is that of partnership with northern and aboriginal communities incorporating traditional and local knowledge. Particularly with Canada's ARR focus on Arctic research, such partnerships are essential if our science is to provide benefit to peoples who are some of those most strongly affected by climate change.

Throughout the meeting, panelists and other participants had several comments on **research support and research funding**. The following summarizes comments made on these issues:

- The serious issues of the timescale and predictability of research support needs to be articulated by the ARRCU community. Interruptions in funding, such as the end of the CFCAS programs, means that expertise built up over a long time period is lost to the detriment of all involved including the broader Canadian society. The CCAR Network cycle is nearing its midpoint, and the issue of research support for the networks that have been assembled will soon arise again. The timescales for internationally coordinated ARR research typically exceed funding cycles of three to five years and so need long-term support to be viable. Furthermore, the ARR community lacks the flexible access to funding for research opportunities that arise relatively quickly, such as opportunities to participate in international field campaigns. This lack of opportunity places Canadian researchers at a competitive disadvantage for future participation and collaborations on an international level.

- Another overarching issue is the scale of research funding. The strong focus on large-scale initiatives and networks means that opportunities for small-to-medium scale projects with shorter term objectives in innovative research areas can be lost.

- A possible path for improved funding to the ARR community would be to expand the scope of NSERC Strategic Grants to allow more areas of ARR research and to facilitate partnership with government departments like EC in such proposals.

- New models of funding should be considered. Flexible funding that is responsive to new ideas emerging from collaborations at the frontiers of different disciplines would help to bring this community together. The ARRCU community would benefit from additional funding to collaborate actively within international teams, for example to use data coming from a new satellite instrument from a non-Canadian space agency for applications of importance to Canada.

- Concern was expressed that the need to provide extensive reporting can have adverse effects on partnerships, because the time devoted to reporting removes time from the actual research. Large-scale network projects like the CCAR projects also increase administrative responsibility on university faculty.

- On computing, ARRCU's strategic plan should articulate its justification of the compute cycles and storage resources needed.

Conclusion

In the time since the May 8 workshop, further consultation and solicitation of interest through a survey and presentations at an EC Carbon Assimilation System (EC-CAS) workshop and CMOS congresses have taken place. A webinar hosted by NSERC on June 22, 2015 discussed next steps and the White Paper draft in progress. The final version of the ARRCU White Paper is expected to be completed in August 2015.

The workshop on May 8 and the thoughtful commentary on the draft ARRCU White Paper show that our community has an abundance of good ideas and commitment to engage in a long-range planning activity. We hope that this activity will achieve the purpose of articulating the academic community's contribution to a long-range strategic plan comprising a sustainable research program in ARR for Canada. We invite further engagement by the broad community of researchers interested in this initiative. Interested university faculty and professional researchers in government laboratories and industry are welcome to join our email list and online meetings. Endorsement of this activity will be more formally indicated by being a signatory to the White Paper that we aim to finalize in the summer of 2015.

ARRCU-Working Group Committee and Panel Members

ARRCU-WG Committee	Panel 1: Scope	Panel 2: Priorities	Panel 3: Partnerships
Chair: Paul Kushner University of Toronto, Department of Physics	**Chair: Kimberly Strong** University of Toronto, Department of Physics	**Chair: Pierre Gauthier** Université du Québec à Montréal, Département des Sciences de la Terre et de l'Atmosphère	**Chair: John Gyakum** McGill University, Department of Atmospheric and Ocean Sciences
Pierre Gauthier Université du Québec à Montréal, Département des Sciences de la Terre et de l'Atmosphère	**Adam Bourassa** University of Saskatchewan, Institute of Space and Atmospheric Studies	**Peter Taylor** York University, Department of Earth and Space Science and Engineering	**Elizabeth Boston** NSERC
John Gyakum McGill University, Department of Atmospheric and Ocean Sciences	**Jennifer Murphy** University of Toronto, Department of Chemistry	**James Drummond** Dalhousie University, Department of Physics and Atmospheric Science	**Gilbert Brunet** EC, Meteorological Research Division
Paul Myers University of Alberta, Department of Earth and Atmospheric Sciences	**John Pomeroy** University of Saskatchewan, Centre for Hydrology	**Paul Myers** University of Alberta, Department of Earth and Atmospheric Sciences	**Madjid Fekri** Pelmorex Media
Kimberley Strong University of Toronto, Department of Physics	**Nigel Roulet** McGill University, Department of Geography	**Randall Martin** Dalhousie University, Department of Physics and Atmospheric Science	**Charles Lin** EC, Atmospheric Science and Technology Directorate
Roland Stull University of British Columbia, Department of Earth Ocean & Atmospheric Sciences	**Gordon Swaters** University of Alberta, Pacific Institute for the Mathematical Sciences	**Peter Bartello** McGill University, Department of Atmospheric and Ocean Sciences	**Thomas Piekutowski** Canadian Space Agency, Sun-Earth System Sciences
Peter Taylor York University, Department of Earth and Space Science and Engineering	**Francis Zwiers** University of Victoria, Pacific Climate Impacts Consortium	**Laxmi Sushama** Université du Québec à Montréal, Département des Sciences de la Terre et de l'Atmosphère	**Iain Russell** Pelmorex Media