Advancing the field of Atmospheric Sciences

Dr Allan Bertram details the innovative research project that he is leading into atmospheric aerosol particles, and outlines why a collaborative approach is essential for this work

To begin, what inspired your interest in important chemical and physical processes in the atmosphere and the work on your current project?

When I was conducting my undergraduate degree in chemistry, the formation of an ozone hole over Antarctica was at the forefront of scientific research. I started reading about this research and found it fascinating. This research motivated my interest in important chemical and physical processes in the atmosphere. My latest project is CREATE – Atmospheric Aerosol Program (AAP). The main aim of this work is to establish a unified training programme and collaborative research environment on atmospheric aerosols and their effects on climate, air quality and health.

Why do studies into atmospheric aerosols require a multidisciplinary approach?

Atmospheric aerosol particles, which range in size from 10-10,000 nanometres, can affect the Earth's climate by scattering and absorbing solar radiation, and by modifying the nucleation and reflectivity of clouds. Aerosol particles also negatively affect air quality and are largely responsible for visibility reduction in urban environments. Elevated levels of aerosol particles are now strongly correlated with increased cardio-pulmonary morbidity. The borders between traditional disciplines are prohibitive when addressing the role that atmospheric aerosols play in climate, air quality and health. This is because atmospheric aerosols and the way that they affect climate, air quality and health span several different fields. For instance, the effect of atmospheric aerosols on climate alone encompasses chemistry, physics, engineering, atmospheric science and public policy. Ice clouds are another example, as they can reflect and absorb solar radiation and radiation given off by the Earth's surface and are very complex. By reflecting and absorbing this radiation these clouds impact the Earth's radiation budget and hence climate. Since these clouds can impact climate, it is crucial to understand if human activity is influencing the properties and frequency of these clouds and this requires a multidisciplinary approach.

How do you aim to identify key heterogeneous reactions that are important in the atmosphere?

Atmospheric heterogeneous reactions are simulated and probed in the laboratory using aerosol reaction chambers, flow tube reactors, and advanced spectroscopic techniques. From the laboratory data we determine the fundamental kinetics and mechanisms of these reactions and develop theoretical frameworks and mathematical models for incorporation into atmospheric models. Examples of heterogeneous reactions we have studied in the past are reactions between NO3 radicals and a wide range of organic aerosol particles and reactions between O3 and organic particles from meat-cooking operations. Tools that my research group utilises include specialised microscopes to determine the morphology and physical state (ie. solid vs liquid) of atmospheric particles and mass spectrometres to determine the chemical composition of these particles. We also use a range of chambers to simulate atmospheric conditions in the laboratory. For example, in one experiment we use special chambers to simulate cloud formation.

What methods are you using to carry out on-going evaluation of the CREATE-AAP programme structure and delivery?

Jackie Stewart, from the University of British Columbia's Chemistry Department, and Gülnur Birol, based at the University of British Columbia's Science Centre for Learning and Teaching, both experts in science education, have been conducting interviews of the CREATE-AAP trainees to determine the effectiveness of the programme and provide feedback on ways to improve the programme. In addition, student evaluations are being used to assess and improve the new courses associated with CREATE-AAP. Input from students and from supervisors of the internships is being used to evaluate and improve internships.

Why is it that atmospheric aerosols remain so poorly understood from a scientific standpoint? What are the main obstacles to progress in this field?

Part of the reason is that atmospheric aerosol particles are very complex. As a simple example, the size of atmospheric aerosol particles can vary by three orders of magnitude and a single particle can consist of hundreds to thousands of different species. Another reason is that research in the area of atmospheric aerosols has, to date, been relatively limited. However, atmospheric aerosol research has witnessed an explosion in scientific interest recently (by several metrics, including growth in research publications on the topic). Progress in this field is expected to continue at a fast pace with a combination of field, laboratory and modelling studies and I see CREATE-AAP as being a key part to support this progression.

Unifying atmospheric aerosol training

A collaborative, tertiary and industry-based programme, **CREATE-AAP**, has established a unique opportunity which is helping to prepare students for a career in the environmental and health sectors

SINCE THE DISCOVERY of the ozone layer above the Antarctic, the field of atmospheric sciences has become increasingly critical in helping to unravel the complexities of relationships between the biosphere and the atmosphere. Now a new joint research and teaching programme is attempting to support this sector by training students in atmospheric aerosols and exposing them to the wider industry through a range of tools and mechanisms. Funded by the National Sciences and Engineering Research Council of Canada (NSERC), the programme is called the Collaborative Research and Training Experience – Atmospheric Aerosol Program (CREATE-AAP). Led by the University of British Columbia (UBC), its main aim is to unify training and fellowship-funding to help develop interdisciplinary skills for atmospheric aerosol researchers; ranging from undergraduate to graduate students.

The multidisciplinary nature of atmospheric aerosols has, for many years, presented quite a challenge for researchers and it is this which has driven the collaboration of UBC experts to broaden the training of graduates and undergraduates. The intention is that, instead of the students simply being trained in the more traditional disciplines, such as chemistry, physics and engineering, they will be exposed to cross-discipline training and industry experiences. The hope is that by offering students greater insights into the important environmental and health challenges faced by the world, they will be better prepared to assist industry and government when they enter the workforce.

A MUTUALLY-BENEFICIAL RESEARCH ENVIRONMENT

Each year, 10 graduate students, five undergraduate students and one postdoctoral fellow are funded through the CREATE-AAP system. In addition, another 40-55 graduate students, funded by other sources, will have the opportunity to be involved in the programme. One of the key areas that CREATE-AAP is focused on are the current deficiencies that have been observed in the training of students. It is proposed that this will be achieved by utilising a number of different tools, including: specially developed courses, a bi-weekly seminar series, a journal club, an annual symposium and a series of internal and external internships. In addition, the students will be exposed to a wide range of activities and skills such as workshops on communicating with the media, and presentation, project management and instructional skills.

Responsible for overseeing the vision of CREATE-AAP is Dr Allan Bertram, a Professor at the UBC's Department of Chemistry. Bertram notes that one of the most important aspects of achieving the training vision is the external internships which offer students a real insight into the challenges and benefits of being able to apply the knowledge they have gained out in the workplace. The internships operate by providing each student with a several-month rotation with national or international partners who have an interest in environmental or health issues; including government agencies, environmental consulting companies and large international research institutions. "Through external internships, trainees are exposed to potential employers, have the opportunity to participate in collaborative research and will enjoy access to research infrastructure that is not currently available in Canada," observes Bertram.

In addition to the internships, students are involved in research projects that are important for progressing the field of atmospheric aerosol research, science and policy. These projects include Population Exposure to Aerosols in Western Canada, Health Impacts of Aerosols, Aerosol/Cloud/Climate Interactions, and the Effect of Transportation Fuel on Climate-Relevant Properties of Aerosols.

ATTRACTING STUDENTS FROM DIVERSE BACKGROUNDS

The key target audience for this programme is graduate students and undergraduate students, both national and international, who have a particular interest in studying atmospheric aerosols. Students that are involved in the training will gain both a degree from their chosen department as well as a CREATE-AAP certificate, which confirms and highlights their involvement in the training. The goal of this is to foster an interest in the role that atmospheric aerosols play in the environment and health specifically in students who are already showing a passion for this topic. The staff and teachers who have agreed to support the project come from a wide range of backgrounds, including chemistry, engineering, meteorology, climate, air quality, health and environmental policy. They

GROUP OF CREATE-AAP PARTICIPANTS, JULY 2012

are able to underpin their own individual expertise with an in-depth knowledge about atmospheric aerosol particles. This means that each of the staff members will be able to offer a unique but complementary understanding of how these particles impact the world around us.

Attracting talented young scientists to participate in programmes like this can be challenging. To assist with overcoming this, a dedicated CREATE-AAP website has been developed which assists people that are interested in understanding more about what the programme offers and how it might be of benefit to them. Links are provided to other faculty websites which mean the departments that are a part of the training can gain extra coverage by promoting their involvement. The website also provides some of the latest updates in global atmospheric aerosol news and a place where students can go to access this information. In addition, they use email distribution lists to advertise a number of graduate student fellowships that are available to participating students.

EXPOSURE TO INDUSTRY LEADERS

As part of the fortnightly seminar series, which are mandatory for all participants, each student is expected to present one class each year. External speakers are also invited, which provides the opportunity for students to hear from people working in the sector known either nationally or globally for their particular research. The benefit of having industry speakers is that students are exposed to many of the latest developments in atmospheric aerosols, climate, air quality and health. The UBC staff that facilitate this part of the programme regard the seminars as being an important part of supporting closer interaction between the trainees and encourage an increased exchange of intellectual ideas across the disciplines.

The internal internships are a welcome chance for students to build on knowledge gained in both the actual courses and the seminar series to broaden their awareness across different fields. These internships support them to work in other laboratories within UBC and strengthen both their practical skills and understanding. For instance, Bertram says that some of his students who have been focused on field measurements of atmospheric aerosols will spend up to two months in his colleague Dr Ian McKendry's laboratory investigating how aerosols are transported and learning more about how these models apply to their field measurements. Each of the students are then expected to share what they have learnt during the internal internship at the seminar series: "This kind of opportunity offers students a unique chance to start to develop a complete picture of atmospheric aerosols and their role in the environment that would be difficult to gain otherwise," highlights Bertram.

BROADENING HORIZONS

One of the areas the CREATE-APP team regards as innately important to the support of interdisciplinary collaboration is the summer undergraduate student fellowships that the programme facilitates each year. Each of the students that are awarded a fellowship is given a particular research project that they will work on with a faculty member and a laboratory at UBC. The purpose behind these awards is to underpin interdisciplinary research and provide the students with a chance to go beyond their chosen degree programme. Two of the awards are set aside specifically for students who are interested in entering the programme from other universities, which helps to encourage inter-university mobility. Likewise, these fellowships serve as an important recruiting tool for encouraging future graduate students to make use of the different faculties at UBC which are concerned with atmospheric aerosols.

Each year the group arranges a one-day conference known as the Symposium on Atmospheric Aerosols. The first symposium was held in May 2010, with 17 attendees from governmental and academic departments. The second symposium, held in June 2011, consisted of 21 attendants and included five plenary talks and 10 poster presentations prepared by the CREATE-APP faculty and students. These symposiums provide many benefits to UBC and in particular provide exposure to its deserving students.

It provides a chance for the community in British Columbia to support stronger relationships with other universities, government agencies and the private sector, as Bertram notes: "This symposium is a chance to advertise the CREATE–AAP programme to a wider audience and recruit collaborators for the programme". Because the symposium and other key components of the programme were so effective in establishing and fostering interdisciplinary research and training, they have decided to significantly expand upon what was originally proposed in the NSERC funding application.

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QUALITY IS A SIGN OF SUCCESS

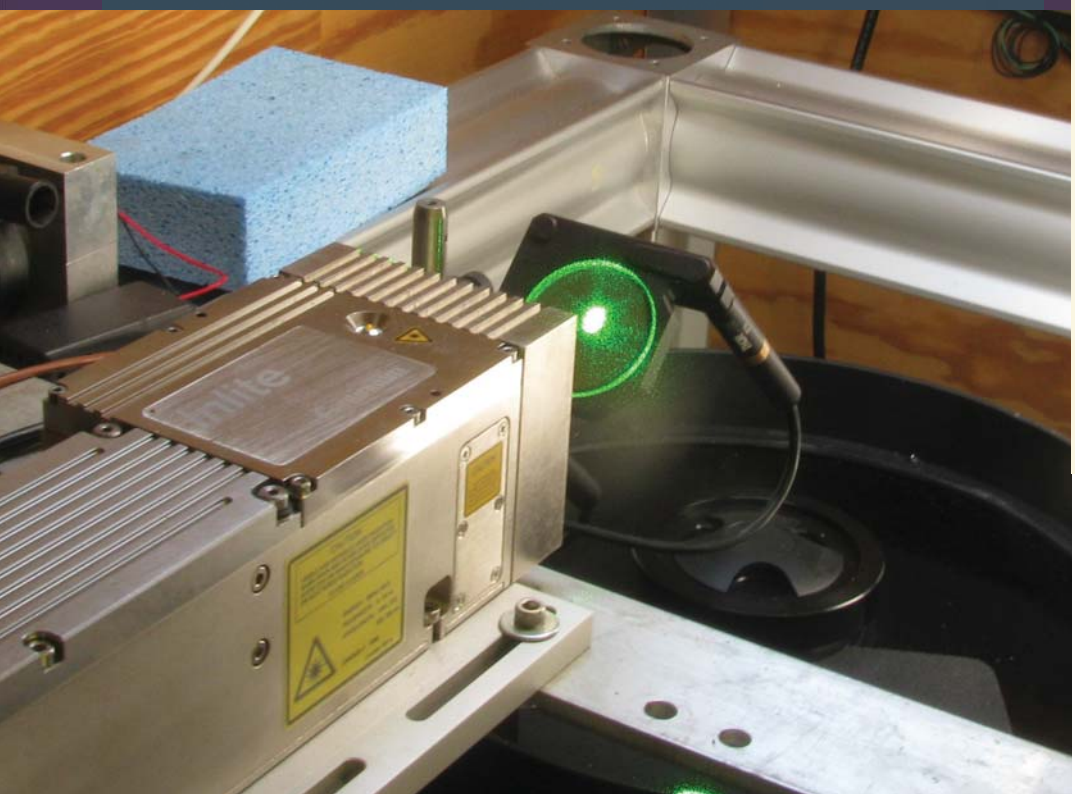
The collaborative approach has already produced a number of important accomplishments, such as the valuable internships that have been created through the close relationships developed by the staff. Yet, the greatest achievement is clearly the superior quality of the students trained by the programme. As a result of these successful internships, students have gone on to work for environmental consulting companies, helping to develop policy recommendations for short-lived climate forcers, and procured internships at Environment Canada, measuring background levels of atmospheric aerosol particles on the west coast. Such practical work experience is generally hard to come by and access, but with the support of CREATE-AAP they are now able to gain valuable real-world training during their studies.

The success or failure of such a training opportunity often hinges upon the capacity that students have to enter jobs and careers in relevant fields and consequently influence the wider industry. For the students who are partaking in CREATE-AAP, it is hoped that by receiving broad practical training in atmospheric aerosols they will be ready and able to work in environmental consulting companies or government agencies with an environmental or health remit, and that the CREATE-AAP students, will be actively sought after by industry.

In order to gauge whether the programme has been successful, the project team are tracking the career paths of all of the trainees closely: "The most important performance indicator will be the numbers of trainees that successfully find relevant positions in industry, academia or the public sector," Bertram points out.

The faculty staff and students involved in this partnership are positive about the future and believe that there are many opportunities for them to continue to strengthen the programme. Students have been very positive about the internship opportunities, which they see as being a key and valuable part of the training. After collating the feedback from students that have successfully completed the internship to date, some expressed that the enhancement of communication between students and potential hosts of the internships may be helpful. Therefore, in line with this proposal they have planned a number of ways to enhance this aspect of CREATE-AAP and as Bertram outlines: "We plan on improving communication using a few different mechanisms, including hosting an information session and offering seminars with invited speakers from industry and government agencies". The CREATE-AAP project continues undeterred and is set to have a lasting impact that will have far reaching implications for both the participating students and Canadian research in general.

Experimental apparatus used by one of the CREATE-AAP fellows (Paul Cottle) to measure the verical profile of atmospheric aerosols.



INTELLIGENCE

CREATE-AAP

COLLABORATIVE RESEARCH AND TRAINING EXPERIENCE ATMOSPHERIC AEROSOL TRAINING PROGRAM

OBJECTIVES

To provide students with interdisciplinary training and experience, particularly focusing on atmospheric aerosols and their relationship to climate, air quality and health.

KEY COLLABORATORS

Michael Brauer • Philip Austin • Hadi Dowlatabadi • Douw Steyn • Ruth Signorell • Steven Rogak • Chris Carlsten • Ian McKendry • Milind Kandlikar

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ALLAN BERTRAM is a Professor of Chemistry at the University of British Columbia and the Director of the Collaborative Research and Training Experience–Atmospheric Aerosol Program (CREATE–AAP). Bertram obtained his BSc from the University of Prince Edward Island (1993) and his PhD from the University of Waterloo (James Sloan, 1998), and he carried out his postdoctoral research at the Massachusetts Institute of Technology (Mario Molina, 1998-2000). Bertram's research focuses on ice nucleation, phase transitions and reactivity of aerosol particles and their connections with climate and atmospheric chemistry.

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