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A CANADIAN RESEARCH ICEBREAKER TO STUDY THE CHANGING ARCTIC OCEAN

Louis Fortier

Climate warming will be particularly intense over the Arctic and several observations tend to confirm that the arctic ice cover has already started to melt. The consequences of an ice-free Arctic Ocean will be far-reaching. They include potential extinction of unique arctic fauna, disruption of oceanic circulation, accelerated climate warming, the opening of a new ocean to resource exploitation and navigation, and major socio-economic and geo-political perturbations that will impact the entire Northern Hemisphere.

The international scientific community unanimously recognizes the acute need for direct observation and measurement of oceanographic conditions and processes in the Arctic Ocean to improve the climate models that attempt to predict the rate and extent of global warming. This has led arctic states and several non-arctic countries of the G7 to accelerate their national efforts in arctic oceanography. Germany is leading a comprehensive international program organized around its research icebreaker *Polarstern.* The US program in arctic oceanography has received a formidable boost with the launch of the research icebreaker *Healy.* Japan has increased efforts in the Arctic with support from the ice-reinforced research ship *Mirai.* The icebreaker *Oden* supports Sweden's program. Even China is now deploying a 150-m icebreaker, the *Xuelong*, to sustain a fast-growing program in arctic oceanography.

Despite obvious arctic responsibilities, Canada has been slow to join in leadership of the international effort to study the Arctic Ocean's response to climate warming; Canada's northern research efforts have consistently dwindled over the last 20 years. The recent Report of the Task Force on Northern Research appointed by the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC) makes a clear case for renewing the historic Canadian leadership in arctic science (Hutchinson *et al.,* 2000, *From Crisis to Opportunity: Rebuilding Canada's Role in Northern Research*). The report identified the present weakness of logistical support as one of the

The CCGS *Pierre Radisson,* sister ship of the CCGS *Sir John Franklin.* Photo: Martin Fortier

As we searched for support for further research we found that the study didn't fit the mandates of most funding agencies. To the credit of the newest and one of the smallest governments in Canada, the Nunavut Department of Health and Social Services considered respiratory infections in children a high priority, and readily agreed to support further research..

In January 2002 we initiated the next phase. A case-control study, it includes all children under the age of five admitted to Baffin Regional Hospital, again looking at the environmental and infectious factors in lower respiratory tract infection in this population, and specifically exploring the role of SN.

Once we understand the cause of respiratory infections in the Baffin region we can make a real impact. And, one can only hope that the probable contributing factors – smoking, overcrowding and poverty – will be addressed, and the unacceptable rate of respiratory infection in Baffin will become a thing of the past.

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CANADA CLOSING ARCTIC OZONE OBSERVATORY

Kimberly Strong

Located high in the Canadian Arctic, less than 1,000 km from the North Pole, Environment Canada's Arctic Stratospheric Ozone Observatory (ASTRO) has been in operation since 1993, providing us with valuable insight into the state of the ozone layer over northern Canada. Unfortunately, it looks like ASTRO will not be celebrating its tenth anniversary as the facility is being mothballed, saving the federal government about $300,000 a year in basic operating costs. This may sound like a large amount, but for comparison, the cost of hosting the 30-hour Kananaskis G8 Summit is equivalent to running ASTRO for 1,000 years!

ASTRO sits on a mountain ridge near Slidre Fjord on Ellesmere Island, about 15km from the Eureka weather station (80°N, 86°W) in Nunavut. It is ideally located for atmospheric measurements, as the high-latitude high-altitude site offers clear skies through most of the year. In addition, the Arctic vortex, a cold isolated mass of air that acts as a container for the chemical reactions that lead to ozone destruction, regularly passes overhead, allowing observations both inside and outside this chemically perturbed region. This is very useful in helping us unravel the chemical and physical processes that control the stratospheric ozone budget.

The Arctic Stratospheric Ozone Observatory. Photo: M.R. Bassford, University of Toronto

The state-of-the-art ASTRO facility was established by Environment Canada in response to concerns about the future of the thinning ozone layer above the Canadian Arctic. It contains a suite of scientific instruments that measure stratospheric ozone and various trace gases involved in ozone chemistry, as well as atmospheric temperature and aerosol profiles. These instruments (several built by Canadian companies) are operated by scientists from the Meteorological Service of Canada (MSC) and by research partners from several Canadian universities, Japan, and the USA. The Japanese have been particularly active participants, with a number of the instruments having been developed and used by scientists from the Meteorological Research Institute, the Communications Research Laboratory, and Fukuoka and Nagoya Universities.

The importance of ASTRO to global atmospheric measurements was quickly recognized, as it was designated as part of the Arctic primary station of the international Network for the Detection of Stratospheric Change (NDSC), which is co-ordinated by the World Meteorological Organization. The closing of ASTRO thus eliminates a key site in the global effort to monitor the recovery (or not) of the ozone layer after the signing of the Montreal Protocol and its subsequent amendments that regulate the production of ozone-destroying chlorofluorocarbons (CFCs). It also means that Canada, with its huge landmass, including about 30% of the Arctic (above 60°N), regrettably no longer has any fully active sites in the NDSC.

My own connection with ASTRO began in 1999, when we first deployed our new grating spectrometer there as polar night was ending in late February. Students and post-doctoral fellows from my research group continued to take it back to the Arctic for each of the following three winters. Equipping the system to operate in the frigid temperatures at Eureka (often dipping to −50°C) was a challenge, which we met by housing it in a thermostatically controlled weatherproof case that sat on the roof of the ASTRO building. We also automated the operation of the spectrometer, so that we could leave it to make unattended measurements for several months, interactively monitoring it from Toronto, with on-site assistance from the MSC's Eureka station manager as needed.

Our goal has been to make measurements through polar spring, the period when the perturbed stratospheric conditions necessary for ozone destruction occur. The instrument records UV-visible absorption spectra of scattered sunlight at sunrise and sunset, from which concentrations of ozone, NO_2, BrO, and OClO can be derived. It complemented the measurements that were being made at ASTRO by the lidars, infrared and millimetre-wave spectrometers, and Brewer ozone spectrophotometers already installed there.

By combining the high-quality observations made by such a suite of instruments, it is possible to obtain a comprehensive data set that can be used to address outstanding questions regarding the current state and future evolution of the ozone layer. Stratospheric ozone is crucial to the Earth's climate. Its best known role is as a highly effective absorber of harmful UV-B solar radiation that protects the biosphere from radiation which can cause skin cancer and eye damage in humans, harm vegetation and marine organisms, and degrade materials such as plastics and paper. However, the absorption of radiation by ozone is also the dominant source of heating in the stratosphere, influencing stratospheric winds. Decreasing stratospheric ozone concentrations are thus likely to increase the amount of UV-B radiation reaching the ground, to enhance UV-dependent photochemical reactions in the troposphere, to reduce stratospheric temperatures, and to possibly change the dynamics of the stratosphere. In fact, measurements made with Environment Canada's Brewer ozone spectrophotometer have provided evidence for the link between ozone depletion and UV increases.

Stratospheric ozone concentrations have declined significantly since about 1980 in response to enhanced levels of chlorine resulting from anthropogenic emissions of CFCs. This is particularly true in the polar regions, with dramatic declines in ozone observed over Antarctica in late winter and early spring. During the 1990s, springtime losses in lower stratospheric ozone have frequently been observed over Arctic regions, with very low ozone column amounts recorded in several recent years, including cumulative ozone losses of 60% at 18km seen in early 2000. Over the Canadian high Arctic, there has been an average decline of about 12% over the past two decades.

Polar ozone depletion is a seasonal effect, which begins with the formation of polar stratospheric clouds (PSCs) in the vortex during the cold polar winter. Heterogeneous reactions on the surfaces of these clouds convert chemically inactive chlorine into a more reactive form, and when sunlight returns in the spring it releases chlorine

Installing our spectrometer on the roof of ASTRO in spring 2001. Shown in photo are Dr. Stella Melo and Elham Farahani from the University of Toronto, and Vivek Voora, Dr. Richard Mittermeier, and Dr. Hans Fast from the Meteorological Service of Canada. Photo: Y. Makino, Japan Meteorological Agency atoms which destroy ozone in a catalytic cycle. This continues until the Sun causes a dynamical breakdown of the winter vortex and PSCs evaporate.

To date, springtime ozone loss has been less severe over the Arctic than over Antarctica because Arctic stratospheric temperatures are generally higher, resulting in less frequent formation of PSCs, which are necessary for the chemistry that leads to ozone destruction. However, concern over Arctic ozone is growing, as models suggest that increasing greenhouse gas concentrations may lead to a colder Arctic stratosphere. (While greenhouse gases warm the lower atmosphere, this trapping of heat near the surface actually cools the stratosphere.) This in turn is predicted to cause further Arctic ozone depletion that will peak during the next 10 to 20 years, with a possible reduction of up to 2/3 in the total ozone column. It was ASTRO measurements that provided the first evidence that global warming was increasing ozone loss in the high Arctic.

The need for the kind of observations that are possible at ASTRO is thus greater than ever. Will the mitigating effects of the Montreal Protocol and its amendments for the reduction of CFCs be counteracted by rising greenhouse gas concentrations and an associated decrease in stratospheric temperatures? What will be the impact of the changing concentrations of other constituents, such as methane, nitrous oxide, water vapour, and sulphate aerosols? Without long-term monitoring of ozone, CFCs, aerosols, temperature, and the chlorine, bromine, and nitrogen compounds that all play a part in ozone chemistry, we can only guess. It is critical that Canada continue to make such long-term measurements if we are to have a role in the international effort to understand climate change. Such data is also important for the validation of satellite measurements, such as those that will be made by Canada's SCISAT-1 mission when it is launched in 2003.

View from ASTRO. Photo: M.R. Bassford, University of Toronto

The closing of ASTRO is symptomatic of Canada's declining commitment to northern research. That this is in "deep crisis" was recognized in the National Task Force Report, "*From Crisis to Opportunity: Rebuilding Canada's Role in Northern Research*", released in 2000. Increasingly, studies in the Canadian Arctic are being undertaken by scientists from other nations, who realize the importance of this region as an early warning system for global change (see "Tundra Northwest 99", *Meridian,* Fall/ Winter, 2001). Canadian government cutbacks over the past decade have had a severe impact on our research capability, particularly with regard to northern science and environmental monitoring. For example, Environment Canada's budget was cut from $800 million in 1988 to $550 million in 1998, making it the smallest federal government department. Although it has since been increased to about $650 million, this reduction has had a direct impact on the research budget of Environment Canada scientists. Some have departed in frustration, while those remaining are left with such difficult decisions as whether to close ASTRO, cut other equally important research projects, or delay repairs to the aging infrastructure of meteorological stations.

What of the future? Next year, we may deploy our spectrometer at Resolute Bay, where there is an observatory managed by SRI International on behalf of the US National Science Foundation. However, the measurements being done there are of the upper atmosphere, not the stratosphere, so it will no longer be possible to combine our measurements with those of complementary instruments, as we have been doing at ASTRO. Unfortunately, this will limit the scientific value of the data we collect.

In the longer term, we hope that funds to reopen ASTRO can be found, given its importance to Canadian and international Arctic science. Ideally, this would continue to be the responsibility of Environment Canada, as the federal government has an important role in long-term monitoring of the atmosphere. It is more difficult for such a facility to be operated by universities, for example, given the relatively short-term nature of graduate student and post-doctoral positions. However, many scientists, both in Canada and abroad, are sufficiently shocked and dismayed by the recent mothballing of ASTRO that we are trying to assemble a consortium of university and government partners to save it. To really operate the facility at full capacity, at least $1 million per year would be needed. This undertaking, being led by my colleague Professor Jim Drummond of the University of Toronto, is still in the early stages and will require significant effort and resources if it is to be successful, but we are convinced that it is vital that ASTRO be kept open. Canada has an obligation to its own population and to the global community to do its part in monitoring the Arctic stratosphere in the years ahead, as we try to unravel the complex climate system processes that result in feedbacks between stratospheric ozone and climate change.

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Further Information
For more details on atmospheric research at the University of Toronto, visit atmosp.physics.utoronto.ca.

For information about ASTRO, visit the Environment Canada web site http://exp-studies.tor.ec.gc.ca/e/eureka/eureka.htm.

The National Task Force Report, "*From Crisis to Opportunity: Rebuilding Canada's Role in Northern Research*", is at ftp://ftp.nserc.ca/pub/nserc_pdf/nor/crisis.pdf.

The Network for the Detection of Stratospheric Change web site is ndsc.ncep.noaa.gov/.

EXPLORING FOR GAS HYDRATE IN THE ARCTIC

Adrienne Ethier

Canadians are continually searching for new energy sources to replace depleting and increasingly expensive conventional fossil fuels. One potential new fuel could come from gas hydrate reservoirs found deep below the ocean floor on the continental shelf.

The existence of methane hydrate was first recognized over seventy years ago as an icy sludge that fouled natural gas pipelines. It was dismissed as a nuisance until 1964, when a Russian drilling crew discovered naturally occurring methane hydrate in a Siberian gas field and recognized its possibilities as a resource. Interest in this source of natural gas has since expanded, and gas hydrate is now regarded as holding enormous potential.

Gas hydrate is a crystalline solid that consists of gas molecules trapped within a cage of water molecules, a structure known as a clathrate (Figure 1). Although many gases such as carbon dioxide and hydrogen sulfide can form gas hydrate, methane forms most marine gas hydrate, making it an abundant source of natural gas.

Hydrate can store immense amounts of methane. One volume of water can bind 207 equivalent volumes of methane at atmospheric pressure. A gas hydrate reservoir may contain 170 times more gas than a conventional high pressure natural gas reservoir of equal volume.

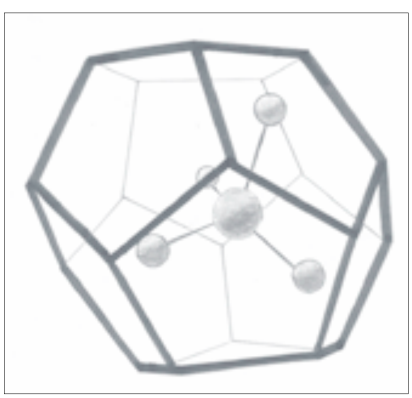

Figure 1

Figure 2

The major factors controlling gas hydrate formation and stability are pressure, temperature, gas chemistry, the salt content of the pore waters, the porosity of the enclosing formation sediments, and the free gas availability and abundance. Gas hydrate exists in nature at high pressure and temperatures near 0°C. Hydrate in sediment dissociates quickly when brought to the surface because of decreased pressure and increased temperature. Sediment will actually pop and fizzle at the surface, as the hydrate decomposes and the highly concentrated methane escapes into the atmosphere.

The sediment can even be set aflame when methane hydrate concentrations are high enough (Figure 2). This phenomenon has led to the term "flammable ice" since the dissociation of gas hydrate freezes the sedi-