The Canadian Baseline Program

Background

The Institute of Ocean Sciences (IOS) initiated the Canadian weekly flask-sampling program for carbon dioxide (CO_2) at Ocean Station P in 1972 and at Alert Nu and Sable Island NS in 1975. In 1982, the measurements at Ocean Weather Station P were replaced by Cape St. James, located on the southeastern tip of St. James Island. In 1988, the Meteorological Service of Canada (MSC) assumed responsibility for the flask measurements of atmospheric CO_2 at Alert, Cape St. James and Sable Island. The west coast measurements at Cape St. James were replaced by Estevan Point due to the closure of the surface-observing program at Cape St. James in 1992. MSC currently operates a small network of stations strategically located to reflect the regional and long-range transport of trace gases into and out of Canada [**Figure 1**]. Alert, located in the High Arctic reflects the long-range transport out of Europe and Siberia. The west coast station of Estevan Point is influenced by the North Pacific and transport out of Asia. Sable Island, located 300 km off the east coast of Nova Scotia is influence by transport out of the eastern part on the North American continent. Fraserdale, located in north central Ontario is strongly influenced by the eastern boreal forest and northern wetland regions around Hudson's Bay. Finally, the Prince Albert station, located in a black spruce forest site near Prince Albert National Park SK and part of the BERMS (Boreal Ecosystem Research and Monitoring Sites) research program is influenced by the western boreal forest.

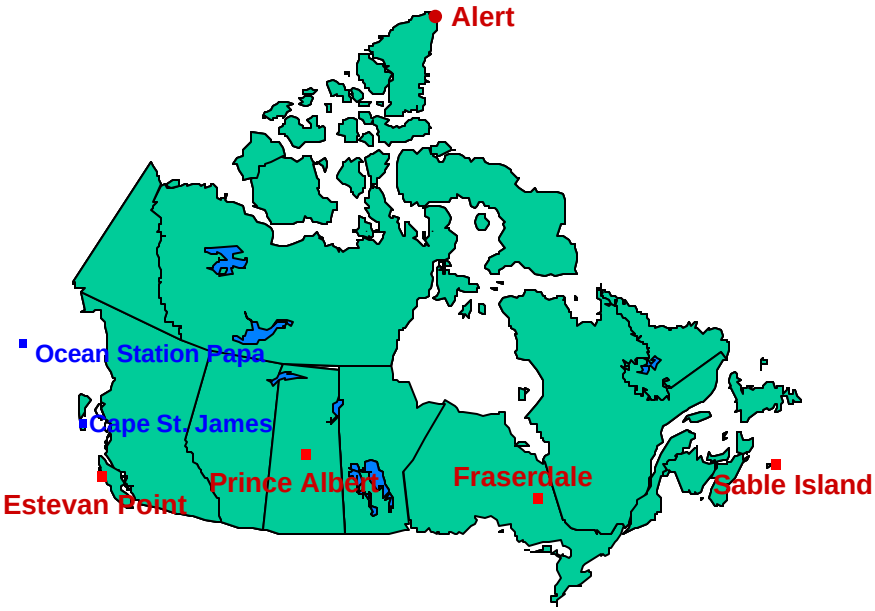


Figure 1. *Location of Canadian baseline measurement sites. The measurements sites at Cape St. James and Ocean Station Papa are no longer in operation.*

MSC has continually developed and enhanced the overall measurement program. In 1986, an Observatory was built in Alert to permit the continuous measurement of CO_2 as well as other greenhouse gases, aerosols and toxic substances. In December 1989, MSC established an observatory, similar to that at Alert, at Fraserdale to measure the annual and seasonal variation in CO_2.and CH_4 in the northern wetlands and boreal forest ecosystems. In 2000, the analysis for CH_4, CO, H_2, N_2O and SF_6 (in addition to CO_2) began from flask samples from all sites, and for the stable isotopes of ^{13}C and ^{18}O in CO_2 from flask samples from Alert, Fraserdale and Estevan Point. In June 2002, continuous measurements of CO_2, CH_4, CO, N_2O and SF_6 began at BERMs, to compliment the continuous CO_2 flux measurement program there with precise measurements of atmospheric CO_2. In 2003, continuous measurements of CO_2, CH_4, CO, N_2O and SF_6 will begin at Sable Island, in order to correctly capture the level of seasonal metabolic activity of the North American biosphere.

Station Summaries

Alert



Alert is the most northerly site in the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) Network. It is located on the northeastern tip of Ellesmere Island in Nunavut at 82º28'N and 62º30'W, far removed from the major industrial regions of the Northern Hemisphere. Alert is also the site of a military station (CFS Alert) staffed with around 60 personnel, and a MSC Upper Air Weather Station. The Alert GAW Observatory is approximately 400 m^2 in size and is situated 210 m above sea level and 6 km SSW of CFS Alert. The observatory has two laboratories that contain analytical equipment, a storage room, pump room and cylinder room, as well as a kitchen and emergency sleeping facilities. Twin 10 m towers attached to the southern end of the facility support intake sampling lines for one laboratory while a separate walk up tower located on the southwestern side of the other laboratory supports a separate intake stack for aerosol measurements as well as intake sample lines for the other continuous trace gas and flask sampling programs. A 10 m meteorological tower located 50 m WSW of the observatory is instrumented for wind and temperature measurements. A detailed climatological description for the Arctic region around Alert can be found in the 1998 Baseline Summary Report

The objective of the program at Alert is to make available on-going background concentration measurements of selected atmospheric constituents and related physical parameters representative of the Canadian Arctic, and to promote scientific studies towards developing a better understanding of the natural biogeochemical cycles and the impact of human activities on these cycles. The atmospheric monitoring activities included in the GAW program are research-oriented rather than routine, providing the scientific and policy-making communities with high quality data from which both communities can fulfill their requisite needs. A team of Canadian scientists, working in partnership with international scientists, maintains the extensive measurement program at Alert. The measurements carried out at the Alert observatory are listed in **Tables 1a and 1b.**

Alert is also a key site for Arctic atmospheric process studies, which have led to the discovery of such phenomena as Arctic haze, important chemical interactions of pollutants with snow surfaces, and rapid changes in the chemical composition of the atmospheric boundary layer during polar sunrise. For example, refer to the reports on pages xxx and yyy for the causes behind the observed springtime depletions in atmospheric mercury and ozone at Alert, and their potential impact on the Arctic environment. Many details of these processes still remain unclear, and further studies are required to fully understand the chemical processes that are occurring and their broader implications. Knowledge gained through these studies contributes to our understanding of Arctic atmospheric processes and helps to improve our ability to accurately predict future climates using atmospheric models.

Table 1a. Measurements carried out at the Alert Observatory by MSC

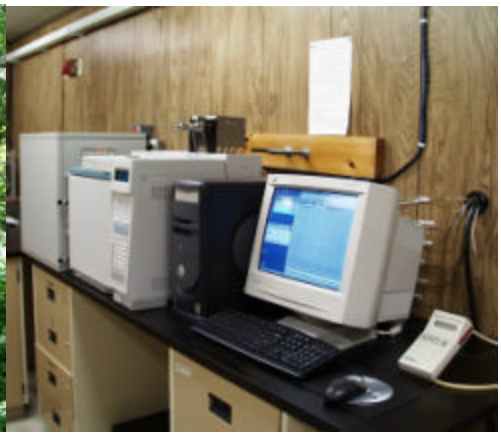
Measurement	Sampling Frequency	Sampling Record
Ozone Vertical Profiles	Bi Weekly	1964 - Present
CO_2	Weekly Flask	1975 - Present
Aerosol Chemistry	Weekly Integrated	1980 - Present
(Major Ions, metals, sulphate & Isotopes)		
Meteorology	Continuous	1985 - Present
(Wind, Temp, Dew Point & Pressure)	Continuous	1986 - Present
Peroxy Acetylnitrate (PAN)	Continuous	1986 - Present
Ozone/UV/SO_2	Continuous	1986 - Present
CO_2	Continuous	1987 - Present
CH_4	Continuous	1987 - Present
Black Carbon	Continuous	1989 - Present
Ozone (surface)	Continuous	1992 - Present
Toxics (PCBs, Ocs)	Weekly Integrated	1993 - Present
Mercury	Continuous	1995 - Present
CFC-11 and CFC-12	Continuous	1995 - Present
CO	Continuous	1998 - Present
H_2	Continuous	1998 - Present
CO_2, CH_4, CO, N_2O, SF_6, ^{13}C and ^{18}O in CO_2	Weekly Flask	1998 - Present
Mercury in Snow	Event Basis (Winter)	1998 - Present
Light Absorption	Continuous	1998 - Present
N_2O	Continuous	2000 - Present
SF_6	Continuous	2000 - Present
Particulate Mercury	Continuous	2001 - Present
Persistent Organic Pollutants (POPs)	Seasonally Integrated	2002 - Present

Table 1b. Measurements carried out at the Alert Observatory by Canadian and International Partners

Measurement	Sampling Frequency	Agency
CO_2, CH_4, CO, N_2O, SF_6, $^{13}C/^{12}C$-CO_2 $^{18}O/^{16}O$-CO_2, $^{13}C/^{12}C$-CH_4	Weekly Flask	CMDL, USA
CO_2, $^{13}C/^{12}C$-CO_2 and $^{18}O/^{16}O$-CO_2	Weekly Flask	SIO, USA
CO_2, CH_4, CO, N_2O, SF_6, $^{13}C/^{12}C$-CO_2 and $^{18}O/^{16}O$-CO_2	Weekly Flask	CSIRO, Australia
Halocarbons, Halons, N_2O and CFCs	Weekly Flask	CMDL, USA
CO_2, $^{13}C/^{12}C$-CO_2 and $^{18}O/^{16}O$-CO_2	Weekly Flask	IOS, Canada
Oxygen	`	SIO, USA
Hydrocarbons	Weekly Flask	York University, Canada
$^{14}C/^{12}C$-CO_2	Weekly Integrated	University of Heidelberg, Germany
$^{13}C/^{12}C$-CH_4; $^{2}H/H$-CH_4, CH_4 and N_2O	Weekly Integrated	University of Heidelberg, Germany
^{222}Radon	Continuous	University of Heidelberg, Germany
Halocarbons (CH_3Br and CH_3I)	Weekly Flask	NIES, Japan
Precipitation-gross beta measurements	Monthly Integrated	H&W Canada
Gamma Radiation	Seasonally Integrated	H&W Canada
$^{18}O/^{16}O$-H_2O; $^{2}H/H$-H_2O	Weekly Integrated	University of Heidelberg, Germany

Fraserdale





Although the primary atmospheric greenhouse gases, CO_2 and CH_4, are measured at many locations around the world, most of the measurement sites are deliberately situated in regions that are remote from terrestrial sources and sinks. It has become apparent though, that for individual source region apportionment, and to better address the role of the terrestrial biosphere in the global atmospheric carbon cycle, it is necessary to establish observatories in mid-continental areas, including wetland regions. In December 1989, a Baseline Air Chemistry Observatory was established at Fraserdale, Canada, the first continental observational site in North America making and reporting continuous atmospheric measurements of CO_2 and CH_4. Today, there are ten or so similar programs scattered around the continental regions of North America. The objective of the Fraserdale program is to measure the annual and seasonal variations of CO_2 and CH_4 in the northern wetlands and boreal forest ecosystems, from which estimates of the uptake of carbon by the boreal forest and the release of CH_4 from the wetlands may be made. A study to estimate CH_4 emissions from the Hudson Bay Lowlands using continuous CH_4 measurements from Fraserdale and Alert can be found on pages yy.y to zz.z Due to financial constraints, the observatory was closed In December 1996, but was reopened in June 1998, when funding was reinstated in recognition of the importance of such a continental site. The observatory consists of two trailers (4 m by 10 m each connected in a "T" configuration) housing analytical equipment and storage and office facilities. Approximately 10 m southwest of the observatory is a 40 m high standard triangular tower equipped with instruments for meteorology and multiple gas sampling lines. The current measurement programs carried out at Fraserdale are listed in **Table 2.**

Table 2. Measurements carried out at the Fraserdale Observatory

Measurement	Sampling Record
Meteorology (Wind, Temp and Humidity, 4 levels)	1990-1996; June 1998 - Present
CO_2 and CH_4	1990-1996; June 1998 - Present
^{222}Radon	1995-1996; June 1998 - Present
N_2O and SF_6	June 1998 - Present
Flask (CO_2, CH_4, N_2O, SF_6 ^{13}C and ^{18}O in CO_2)	June 1998 - Present
CO	October 2002 - Present
Aerosols	October 2002 - Present

The observatory is located on the southern perimeter of the Hudson Bay Lowland and on the northern edge of the boreal forest at 49°53'N, 81°34'W at an elevation of 210m above sea level. The observatory is situated in a small clearing of approximately 1 km^2 at the edge of a reservoir formed by a hydroelectric generating dam on the Abitibi River at the head of the Abitibi canyon. The station is located within a region that has extensive wetland coverage. The terrain in the surrounding area is slightly rolling with extensive areas of impeded drainage. It contains a mixture of black and white spruce, balsam fir, white birch, maple and trembling aspen. A detailed climatological description of the region is found in the 1998 Baseline Summary Report. The Fraserdale site has also played host to intensive study campaigns that included continuous CO_2 measurement profiles from aircraft (for both morning and afternoon) and surface diurnal isotopic CO_2 studies in June 1998, July 1999 and August 2000. Results from these campaigns, including boundary layer modeling interpretations of the measurements have been described in two separate reports starting on pages xxx and yyy.

Prince Albert (BERMs)



In 1994 and 1996 Canadian and US government agencies headed up the Boreal Ecosystem-Atmosphere study (BOREAS). BOREAS was a large-scale international interdisciplinary experiment in the northern boreal forests of Canada (Refer to http://www-eosdis.ornl.gov/BOREAS/bhs/BOREAS_Home.html for further details). The objective of the program was to further understand the interactions of the boreal forest with the atmosphere, determine how much CO_2 the forests could hold and how the forests might respond to changes in climate. While much was learned about boreal forest processes, it was agreed that there were still many unanswered scientific questions. For example, since the BOREAS years were wetter than normal, scientists did not get a chance to study how the boreal forest might respond to drought.

Although the BOREAS program was completed in November 1996, several sites continued, including the sites in Saskatchewan, under the new study heading of the Boreal Ecosystem Research and Monitoring Sites (BERMs). There currently are three main study sites in the southern boreal forest of Saskatchewan, each representing a different forest type. Each site is dominated by a particular mature tree species, ranging in age from about 50-150 years. The BERMs program is a joint initiative of Canadian government agencies in collaboration with national and international research partners. Further information on the BERMs program can be found at http://berms.ccrp.ec.gc.ca. The BERMS sites are also part of the Fluxnet-Canada network comprised of seven flux stations in Canada, which is also part of the international Ameriflux network. Measurements at the BERMS sites include the exchanges of CO_2 and water vapor between land and atmosphere plus climatic measurements, such as radiation, temperature, humidity, wind, precipitation and soil moisture. Further information on Fluxnet Canada can be found at http://www.fluxnet-canada.ca/welcome.html. Information on the Ameriflux program can be found at http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm.

Data from flux sites are essential in that they provide a direct measure of ecosystem CO_2 source or sink strength, vital information for validation of ecological models of carbon exchange. At the same time, flux sites are usually specific to one ecosystem type and measure CO_2 exchange over relatively small areas (<1 km^2). Due to the heterogeneity of the terrestrial environment, results from individual flux sites are difficult to extrapolate to regional or continental scales. It's now becoming widely agreed, that accurate continuous measurements of atmospheric CO_2 (<0.1 ppm) as well as CO should be included at flux sites. Accurate CO_2 measurements at flux sites is an essential component of the recently formulated North American Carbon Program; a plan on measuring and understanding sources and sinks of CO_2, CH_4 and CO in North America (Refer to http//www.esig.ucar.edu/nacp for further information). Atmospheric CO_2 observations, when combined with inverse modeling techniques can be used to obtain sources and sinks for atmospheric CO_2 over large spatial scales. There are, however, large uncertainties in such evaluations as well, partly due to uncertainties in the transport as well as ecosystem CO_2 exchange being derived from very small concentration differences amongst sites. Nevertheless, the two approaches (flux and concentration measurements, often referred to as "bottom-up" and "top-down" respectively) compliment each other and provide independent analyses for the same unknown.

In June 2002, continuous measurements of CO_2, CH_4, CO, N_2O and SF_6 begun at the BERMs old black spruce (OBS) forest site. A weekly flask-sampling program for isotopic analysis of ^{13}C and ^{18}O in CO_2 was also added. The OBS site is located approximately 100km NE of Prince Albert at 53º59'N and -105º7'W. The vegetation is mostly black spruce, but approximately 15% of the forest consists of deciduous-type larch. Further information on the OBS site can be found at http://berms.ccrp.ec.gc.ca. The OBS site has also played host to a 5-day aircraft continuous CO_2 measurement campaign in 2002 with two additional campaigns being scheduled for 2003 and 2004. The CO_2 profiles for July 2002 are shown on page xx

Sable Island

Sable Island is located at 43°56'N and 60°01'W in the Atlantic Ocean approximately 275 km east-southeast of Halifax, Nova Scotia. The island is predominantly influenced by airflow originating from the North American continent and thus provides an excellent platform to assess the influence of anthropogenic and terrestrial emissions from the North American continent to the troposphere. For example, Sable Island was a crucial site used in the North Atlantic Regional Experiment (NARE), a study to determine the origins and chemistry of continental ozone that passes out to the North Atlantic (see J.G.R Atmospheres, Vol 101, 1996 for further information). The island is in the dry summit of a sea ridge with a maximum elevation of about 10m above sea level. It is approximately 44 km long and a little more than 1 km wide at its widest point.

In 1975, measurements of atmospheric CO_2 collected approximately once per week in discrete Pyrex glass flasks were started at Sable Island. The primary objective of this sampling program was to observe the seasonal and annual variations in the trend and cycle of CO_2. Recent studies using inversion-modeling techniques have placed a higher demand on the accuracy of the weekly flask measurements in order to better estimate the magnitude and distribution of anthropogenic sources and terrestrial sinks. A relatively recent example of an inverse modeling study (Fan et al, Science; October 16th 1998) using an integrated dataset estimated a mean annual net North American uptake equal to the annual emission of CO_2 by fossil fuel burning in Canada and the United States. This study revealed that the inclusion or deletion of CO_2 observations from Sable Island had a large impact, on the order of 30%, on the final North American sink estimate. It's now recognized that the magnitude of this sink inferred in this study is likely high. Nonetheless, the study served to point out the importance of Sable Island, in terms of its location, being the only site located off the northeastern seaboard of the North American continent, as well as the need for high data quality for carbon budgetary investigations.

As described in the paper on Page xxx, an analysis from a 9-month pilot study (August 1992 to April 1993) of continuous CO_2 measurement record showed that CO_2 is highly variable and significantly influenced by air masses from the North American continent. In addition, the continuous CO_2 record showed features that were not captured by the CO_2 flask record, thus pointing toward the need for a continuous monitoring program on the Island. In June 2003, continuous measurements of CO_2, CH_4, CO, N_2O and SF_6 will begin at Sable Island, as part of the Sable Island Airshed Monitoring program, which also includes the additional measurements of NOx, SO_2/H_2S, ozone and PM2.5 carried out by Environment Canada's Atlantic Regional office. The weekly flask-sampling program will continue, initially for quality control purposes, but hopefully in the near future, funding permitting, for the isotopic analysis of ^{13}C and ^{18}O in CO_2 as well.

Estevan Point

Estevan Point is a lighthouse station located in the midsection of Vancouver Island's west coast at 49^{O}N and 126^{O}W. The site can only be reached by boat or helicopter. A northward aerial view of the site during a low tide is shown in the above collage. The beach is about 100 m from the lighthouse. The lighthouse complex is surrounded to the north, east and south by forest and to the west by the Pacific Ocean. In June 1992, a weekly sampling program was initiated at Estevan Point. Samples were initially collected on the beach when winds were greater than 5 m s^{-1} using single valve evacuated flasks. In January 1993, MSC began a pressurized flask-sampling program, using 2-litre double-valve flasks. These samples are taken at the top of the 39-metre lighthouse tower, shown above.

Recently, Estevan Point was chosen as one of the sites for the North American Carbon Program (refer to http//www.esig.ucar.edu/nacp for further information on this plan). Bi weekly multiple flask sampling from aircraft was initiated by NACP at Estevan Point in October 2002. During aircraft sampling, the pilot contacts the operator at Estevan Point so the weekly MSC flask sample can be collected in conjunction with the aircraft profile samples. In the future, it is hoped (funding permitting) that a continuous measurement program, similar to that at Alert, Fraserdale, Prince Albert and Sable Island can be implemented at Estevan Point, in order to adequately capture the regional signal. Such data would be most useful in carbon budgetary studies.