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Sable Island Air Monitoring Program Report: 2003−2006

by:

David Waugh, Tracey Inkpen,
Michael Hingston, Stephanie Keast
Johnny McPherson, Doug Worthy
Gerry Forbes

Air Quality Sciences
Meteorological Service of Canada, Atlantic Region
Environment Canada
45 Alderney Drive
Dartmouth, NS B2Y 2N6

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API	Advanced Pollution Instrumentation model
AQRB	Air Quality Research Branch (MSC)
AST	Atlantic Standard Time
AURAMS	A Unified Regional Air Quality Modelling System
BAM	Beta Attenuation Monitor
CAC	Criteria Air Contaminants
CAPP	Canadian Association of Petroleum Producers
CHRONOS	Canadian Hemispheric and Regional Ozone and NO_x System
CH_4	Methane
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CO	Carbon monoxide
CO_2	Carbon dioxide
CWS	Canada-wide Standards
EC	Environment Canada
ESRF	Environmental Studies Research Fund
ETC	Environmental Technology Centre
FTP	File transfer protocol
GAW	Global Atmospheric Watch
GGML	Greenhouse Gas Measurement Lab
GHG	Greenhouse Gases
GMT	Greenwich Mean Time
H_2S	Hydrogen sulphide
LST	Local Standard Time
MOU	Memorandum of Understanding
MSC	Meteorological Services of Canada
NAPS	National Air Pollution Surveillance (Monitoring Network)
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NRC	National Research Council
O_3	Ozone
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate matter
$PM_{2.5}$	Particulate matter less than or equal to 2.5 microns in diameter
ppb	parts per billion
ppm	parts per million
QA/QC	quality assurance/quality control
SACC	Surveillance of Atmospheric Change in Canada network
SIPT	Sable Island Preservation Trust
SOx	Sulphur oxides
SO_2	Sulphur dioxide
SOEI	Sable Offshore Energy Installation
TEI	Thermo Electron Corporation Environmental Instruments model
$\mu g/m^3$	micrograms per cubic metre
VOC	Volatile Organic Compounds
WHO	World Health Organization
WMO	World Meteorological Organization

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EXECUTIVE SUMMARY

This report provides a summary of the initial set-up and first four years of operation of the Sable Island Air Monitoring Station. The station was supported by the Environmental Studies Research Fund (ESRF) and is operated through the contributions of a number of partners, including the following:

- Environment Canada (EC)
- Canadian Association of Petroleum Producers (CAPP)
- Sable Island Preservation Trust (SIPT)
- Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)
- Nova Scotia Environment

ESRF funding provides for the monitoring of those pollutants that could be associated with offshore oil and gas activity: nitrogen oxides (NOx), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), and fine particulate matter ($PM_{2.5}$). Environment Canada also made use of the program infrastructure to measure ground-level ozone (O_3), and a number of greenhouse gases.

The intent of the Sable Island Monitoring Program is to provide regulators, industry and researchers with the necessary data required to evaluate any impacts on ambient air quality attributable to contaminant emissions from petroleum-related activities. Air quality data from the station are reported to a number of provincial, national and international monitoring programs.

Sable Island's location in the Atlantic ensures that it receives significant transboundary pollutant flows from areas in the Great Lakes and along the US Eastern seaboard. However, there are also localized emission sources that could contribute to the build-up of air pollutants in the area, including offshore oil and gas activity, transportation emissions from air and ship traffic and electricity generation and waste incineration on Sable Island.

Monitoring data is available for 2003 (limited periods), 2004 through 2005 and part of 2006. Until recently, there was at least a six-month lag time in the reporting of air quality monitoring data because of problems with equipment calibration and quality assurance/quality control (QA/QC).

Concentrations of $PM_{2.5}$ on Sable Island were compared to World Health Organization Ambient Air Quality Guidelines for $PM_{2.5}$. All four years had at least one exceedance of the 24-hour Guideline of $25\mu g/m^3$, with 2003 and 2006 containing additional exceedances. Generally, the data show higher $PM_{2.5}$ values in 2006, as compared to the other years, including several extreme values. Annual averages were calculated for the data and these all fell below the Canadian National Ambient Air Quality Objective (NAAQO) for Total Suspended Particulate. However, the World Health Organization annual average for $PM_{2.5}$ was exceeded in 2003 and values were close to this annual average for both 2005 and 2006. The data appear to have met the Canada-wide Standard for $PM_{2.5}$ for the three year period from 2004 to 2006.[1]

Ozone concentrations on Sable Island were compared to the National Ambient Air Quality Objective (NAAQO) for ozone. In all four years, there were numerous exceedances of both the NAAQO 24-hour and 1-hour desirable levels. Annual averages also exceeded the NAAQO

[1] Owing to incomplete data that do not meet the standards of the *Guidance Document on Achievement Determination*, it cannot be definitively stated that the data met the CWS for $PM_{2.5}$.

maximum acceptable level in each year. However, this is similar to background ozone levels observed at rural land-based sites. The data met the Canada-wide Standard for Ozone for the three-year period from 2004 to 2006. As with $PM_{2.5}$, higher ozone levels were recorded in 2006, as compared to the other years.

At the present time, there is no CWS for nitrogen oxides. Concentrations of NOx and NO_2 were compared to the NAAQO and were significantly below both 24-hour maximum acceptable levels and 1-hour maximum acceptable levels. Based on this information, NOx and NO_2 do not appear to be a problem in the Sable Island area at the present time. Higher concentrations seem to be present in the 2005 data.

Concentrations of hydrogen sulphide were compared to current provincial permissible levels. There is no NAAQO or CWS for H_2S at this time. The maximum 1-hour and daily averages were all below Nova Scotia permissible levels. Analysis of the data appears to show levels of H_2S rising since 2004, although this needs to be confirmed with more data.

Sulphur dioxide concentrations were compared to NAAQO. There is currently no CWS for SO_2. Levels of SO_2 were all below the maximum desirable levels for both the 1-hour maximum and 24-hour daily averages. Annual averages were also well below the NAAQO desirable level for SO_2. As with H_2 S data, however, SO_2 levels appear to be rising since 2004.

Based on the monitoring data, several episodes containing elevated pollutant values were identified and analysed using back trajectories and air quality modelling in order to determine an underlying cause for the high values recorded. These high pollutant episodes likely resulted from a number of factors, including long-range transport, emissions from local sources and/or emissions from natural sources.

The analysis revealed that the majority of the events examined seemed to indicate transboundary flows from onshore areas in Canada and/or the US as the main reason behind the elevated pollutant levels. There was also some indication of natural PM events due to sea-salt aerosol loading.

There was some limited evidence of local effects on NOx concentrations as well as possible contributions to $PM_{2.5}$ concentrations from flaring. However, it was not possible to determine the underlying cause of all of the identified pollutant episodes. In particular, based on the available information, the cause of H_2S and SO_2 peaks in the data set was especially hard to attribute to any particular source.

It is difficult to reach firm conclusions regarding the influence of local sources, including offshore oil and gas activity, at this time because of a lack of information on specific local activities and emissions. The current analysis used only limited smoke observation data from the Thebaud offshore platform. Given the potential number of other sources in the area, additional information from project partners will be needed to help refine what influence, if any, these local sources are having on air quality values recorded at the station.

Overall, the Sable Island Monitoring Program has produced some useful results in its first four years of operation. Air monitoring data from this project have shown that Sable Island can be affected by the long-range transport of air pollution from the continental mainland. However, the monitoring program and current observations of various emission-producing activities on and around the island do not yet allow for confirmation as to whether the effects of offshore oil and gas activities can be measured on the island. Continued operation of the station, the use of PM speciation data and better activity observations in the area will help to clarify emission sources that affect Sable Island.

Specific recommendations for the program include increasing the information provided by project partners on emissions from local sources, as well as using additional monitoring data in future analysis to help separate local and long-range influences. Given its early success and the satisfaction expressed by project partners, consideration should be given to extending the Sable Island Air Monitoring Program into the future.

1.0 INTRODUCTION

This report provides a summary of the initial set-up and first four years of operation of the Sable Island Air Monitoring Station. This station was supported by the Environmental Studies Research Fund (ESRF) and is operated through the contributions of a number of partners, including the following:

- Environment Canada−Atlantic Region, Environmental Technology Centre (ETC) and Air Quality Research Branch (AQRB)
- Canadian Association of Petroleum Producers (CAPP)
- Sable Island Preservation Trust (SIPT)
- Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)
- Nova Scotia Environment

The ESRF project supported the monitoring of those pollutants that could be associated with offshore oil and gas activity: nitrogen oxides (NO_x), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) and hydrogen sulphide (H_2S). In order to take advantage of infrastructure needed for this project and an opportunity to share costs (communications, utilities) a broader monitoring program (funded separately) was also incorporated. This additional monitoring includes ground-level ozone (O_3) monitoring carried out by Environment Canada's Atlantic office and the re-establishment of a greenhouse gas (GHG) measurement program carried out by Environment Canada's Air Quality Research Branch. The GHG measurement program monitors methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2) nitrous oxide (N_2O) and sulphur hexafluoride (SF_6) on a continuous basis, while CO_2 isotopes are measured through weekly flask sampling.

Air quality data from this station are available and are currently being reported to the same programs as other air quality data. For example, quality assured NO_x, $PM_{2.5}$ and ozone data are being reported to the National Air Pollution Surveillance (NAPS) network on an annual basis[2], while near real-time ozone and $PM_{2.5}$ data are being reported to the AIRNow program to be included in its real-time mapping program. Raw data are available on request to all project partners in a variety of forms, ranging from annual or weekly summaries to automated, near-real time data transfers.

[2] SO_2 data from Sable are not reported to NAPS at this time since the data are collected every second hour and hence do not comply with NAPS protocols.

INTRODUCTION

Le présent rapport contient un résumé de la configuration initiale et des quatre premières années d'activité de la Station de surveillance de la qualité de l'air de l'île de Sable. Le projet de station était soutenu par le Fonds pour l'étude de l'environnement (FEE) et fonctionne grâce aux contributions d'un certain nombre de partenaires, y compris les suivants :

- Environnement Canada (EC)
- Association canadienne des producteurs pétroliers (ACPP)
- Sable Island Preservation Trust (SIPT)
- Office Canada-Nouvelle-Écosse des hydrocarbures extracôtiers (OCNEHE)
- Nova Scotia Environment

Le financement du FEE est destiné à la surveillance des polluants atmosphériques qui pourraient être associés à l'activité pétrolière et gazière extracôtière : oxydes d'azote (NOx), dioxyde de soufre (SO_2), sulfure d'hydrogène (H_2S) et particules fines ($MP_{2,5}$). Environnement Canada a aussi utilisé l'infrastructure du programme pour mesurer la concentration d'ozone (O_3) au niveau du sol et celle d'un certain nombre de gaz à effet de serre.

Le programme de surveillance de la qualité de l'air de l'île de Sable a pour but de fournir aux organismes de réglementation, à l'industrie et aux chercheurs les données nécessaires pour évaluer les répercussions possibles sur la qualité de l'air ambiant des émissions de contaminants issues des activités liées au pétrole. Les données sur la qualité de l'air de la station sont rapportées à un certain nombre de programmes de surveillance provinciaux, nationaux et internationaux.

En raison de sa situation géographique dans l'Atlantique, l'île de Sable reçoit d'importants apports de polluants transfrontaliers de régions situées dans les Grands Lacs et le long du littoral est des États-Unis. Cependant, il y a aussi des sources d'émissions localisées qui pourraient contribuer à l'accumulation des polluants atmosphériques dans la région, y compris les activités pétrolières et gazières extracôtières, les émissions des transports (de la circulation aérienne et maritime) et la production d'électricité et l'incinération des déchets à l'île de Sable.

Les données sur la surveillance sont disponibles pour 2003 (pour des périodes limitées), 2004 à 2005 et une partie de 2006. Jusqu'à tout récemment, il y avait un retard d'au moins six mois dans la production des rapports sur les données de la surveillance de la qualité de l'air en raison de problèmes d'étalonnage de l'équipement et d'assurance et contrôle de la qualité (AQ/CQ).

Les concentrations de $MP_{2,5}$ à l'île de Sable ont été comparées à celles des lignes directrices de l'Organisation mondiale de la santé sur la qualité de l'air ambiant pour les $MP_{2,5}$. Les quatre années comportaient au moins un dépassement de la concentration de la ligne directrice de 24 heures ($25 \mu g/m^3$) et il y a eu plus d'un dépassement en 2003 et 2006. En général, les données montrent que les valeurs de $MP_{2,5}$ étaient plus élevées en 2006 qu'au cours des autres années (il y avait même plusieurs valeurs extrêmes). Les moyennes annuelles ont été calculées pour les données et celles-ci étaient toutes inférieures aux objectifs nationaux de qualité de l'air ambiant (ONQAA) du Canada pour les particules totales en suspension. Cependant, la moyenne annuelle de l'Organisation mondiale de la santé pour $MP_{2,5}$ a été dépassée en 2003 et les valeurs étaient proches de cette moyenne annuelle en 2005 et 2006. Les données semblent conformes aux normes pancanadiennes sur les $MP_{2,5}$ pour la période de trois ans allant de 2004 à 2006.[3]

Les concentrations d'ozone à l'île de Sable ont été comparées aux objectifs nationaux de qualité de l'air ambiant (ONQAA) pour l'ozone. Au cours des quatre années, il y a eu de nombreux dépassements des niveaux désirables sur 24 heures et sur une heure des ONQAA. Les moyennes annuelles dépassaient également le niveau maximal acceptable des ONQAA chaque année. Cependant, ces concentrations d'ozone sont semblables aux valeurs de fond observées sur des sites ruraux terrestres. Les données étaient conformes aux normes pancanadiennes sur l'ozone pour la période de trois ans allant de 2004 à 2006. Comme pour les $MP_{2,5}$, des teneurs en ozone plus élevées ont été enregistrées en 2006 qu'au cours des autres années.

À l'heure actuelle, il n'y a pas de SP pour les oxydes d'azote. Les concentrations de NOx et de NO_2 ont été comparées aux ONQAA et étaient sensiblement inférieures aux teneurs maximales acceptables sur 24 heures et sur une heure. D'après cette information, le NOx et le NO_2 ne semblent pas poser problème à l'heure actuelle dans la région de l'île de Sable. Des concentrations plus élevées semblent être présentes dans les données de 2005.

Les concentrations de sulfure d'hydrogène ont été comparées aux teneurs qui sont considérées acceptables à l'heure actuelle aux termes des normes provinciales. Il n'y a pas d'ONQAA ou de SP pour le H_2S à l'heure actuelle. Les moyennes maximales sur une heure et quotidiennes étaient toutes sous les niveaux acceptables pour la Nouvelle-Écosse. L'analyse des données semble montrer une hausse des concentrations de H_2S depuis 2004, bien que ceci doive être confirmé par de plus amples données.

Les concentrations de dioxyde de soufre ont été comparées aux ONQAA. À l'heure actuelle, il n'y a pas de SP pour le SO_2. Les concentrations de SO_2 étaient toutes inférieures aux niveaux désirables maximaux pour le maximum sur une heure et les moyennes quotidiennes sur 24 heures. Les moyennes annuelles étaient également bien en deçà du niveau désirable des ONQAA pour le SO_2. Comme dans le cas des données sur le H_2 S, les concentrations de SO_2 semblent en hausse depuis 2004.

À partir des données de la surveillance, plusieurs épisodes de concentrations élevées de polluants ont été relevés et analysés au moyen de la modélisation des rétrotrajectoires et de la qualité de l'air pour déterminer la cause sous-jacente des valeurs élevées enregistrées. Ces épisodes de pollution élevée étaient vraisemblablement la conséquence d'un certain nombre de facteurs, y compris le transport à grande distance, les émissions des sources locales et/ou les émissions des sources naturelles.

L'analyse a révélé que la majorité des événements examinés semblent indiquer que des flux transfrontaliers des régions côtières du Canada et/ou des États-Unis sont la cause principale des concentrations élevées de polluants. Il y avait aussi certains signes d'événements naturels producteurs de particules fines et associés à la charge d'aérosol de sel marin.

Il y avait aussi des preuves limitées de l'existence d'effets locaux sur les concentrations de NOx ainsi que de contributions possibles aux concentrations de $MP_{2,5}$ du brûlage à la torche. Cependant, il n'a pas été possible de déterminer la cause sous-jacente de tous les épisodes de

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[3] En raison du caractère incomplet des données qui ne satisfont pas aux normes du *Guide de vérification de la conformité aux standards pancanadiens*, on ne peut affirmer avec certitude que les données satisfont au critère des SP pour les $MP_{2,5}$.

pollution répertoriés. En particulier, d'après les informations disponibles, la cause des pics de H_2S et de SO_2 dans l'ensemble de données était particulièrement difficile à associer à une source en particulier.

Il est difficile pour le moment de tirer des conclusions définitives en ce qui concerne l'influence des sources locales, y compris l'activité pétrolière et gazière extracôtière, en raison du manque d'information sur les différentes activités et émissions locales. L'analyse actuelle n'a fait appel qu'à des données d'observation limitées sur la fumée de la plate-forme de forage extracôtier de Thebaud. Étant donné le nombre potentiel d'autres sources dans la région, des informations supplémentaires devront être obtenues des partenaires du projet pour mieux préciser l'influence que ces sources locales ont sur les valeurs de la qualité de l'air enregistrées à la station, s'il y a lieu.

Dans l'ensemble, le programme de surveillance de la qualité de l'air de l'île de Sable a produit certains résultats utiles au cours de ses quatre premières années. Les données de surveillance de la qualité de l'air de ce projet ont montré que l'île de Sable peut être touchée par le transport à grande distance de la pollution atmosphérique du continent. Cependant, le programme de surveillance et les observations actuelles de diverses activités productrices d'émissions sur l'île et aux alentours ne permettent pas encore de confirmer que les effets des activités pétrolières et gazières extracôtières peuvent être mesurés sur l'île. Le maintien du fonctionnement de la station, l'utilisation de données de spéciation sur les particules et de meilleures observations des activités dans la région nous aideront à mieux comprendre quelles sources d'émissions touchent l'île de Sable.

En ce qui concerne le programme, il est recommandé entre autres d'accroître le volume des informations fournies par les partenaires du projet sur les émissions des sources locales ainsi que d'utiliser des données de surveillance supplémentaires dans les analyses futures pour mieux distinguer les influences locales des influences à grande distance. Étant donné le succès qu'il a remporté dans ses débuts et la satisfaction exprimée par les partenaires du projet, il faudrait envisager de prolonger la durée du programme de surveillance de la qualité de l'air de l'île de Sable.

2.0 BACKGROUND

2.1 History of the Project

The original rationale for the project became apparent after personnel on Sable Island were exposed to a plume from a flare at the Sable Offshore Energy (SOEI) Installation. The follow-up investigation resulted in a consensus that there was a need for a better understanding of both ambient air concentrations in the Sable Island area and any possible effects from offshore operations. Further discussions led to the conclusion that a multi-stakeholder approach to this work was appropriate, and a proposal for the Sable Island Monitoring Station was submitted to the Environmental Studies Research Fund (ESRF).

The focus of the proposal was to provide baseline information on the ambient air quality on Sable Island and to monitor trends in air quality as development of the Nova Scotia offshore oil and gas exploration expanded. This data would then be available as a basis for a comprehensive air quality management system to identify and address any potential impacts attributable to contaminant emissions from offshore activities. A copy of the proposal submitted to the ESRF is provided in Appendix A.

The proposal was successful, and a memorandum of understanding (MOU) between the ESRF management board and Environment Canada–Atlantic Region was signed for a $100,000 project. A copy of this MOU is provided in Appendix B. The contributing partners involved in the operation of this site (cited in Section 1) drew up and signed an agreement relative to the operation of this site for the first four years. The Terms of Agreement are provided in Appendix C.

2.2 Historical Air Monitoring on Sable Island

There is a long history of air monitoring on Sable Island. Its location, away from significant local point sources (until the development of the offshore) but downwind from highly populated areas of Eastern North America, combined with supporting infrastructure, provided a unique opportunity for a wide range of air-related research as far back as the 1960s. Previous measurements carried out by various governments (Environment Canada and US National Oceanic and Atmospheric Administration) and university researchers include the following:

- pollen measurements
- aerosol particle counting
- precipitation sampling
- soot measurements
- bio-aerosol collection
- toxic components in fog (airborne mercury, organochlorines, heavy metals, PAHs)
- atmospheric oxygen/nitrogen flask sampling
- gaseous pollutants including NO_x, SO_2, O_3, CO, CO_2, hydrocarbons, halocarbons and organochlorines

A complete list of studies and references is available at http://www.greenhorsesociety.com/Bibliography/Bibliography.htm.

2.3 *Emission Sources and Offshore Activities in the Vicinity of Sable Island*

Sable's location in the Atlantic ensures that it receives significant transboundary pollutant flows from areas in the Great Lakes and along the US Eastern seaboard.[4] However, there are also localized emission sources that can contribute to the build-up of air pollutants in the area.

ExxonMobil currently operates five offshore natural gas production platforms in the vicinity of Sable Island. In addition to these producing platforms, drilling activities by a variety of licence holders are taking place to determine potential sources of oil and natural gas. Offshore oil and gas platforms and drilling activities can be a source of various air contaminants, including criteria air contaminants (NO_x, SO_2, VOCs and PM), reduced sulphur compounds and greenhouse gases (CO_2, CH_4). A map of the area showing current production platforms and recent and historical well drilling sites is shown in Figure 1. The location of Deep Panuke, a recently approved project expected to commence production in 2010, is also indicated.

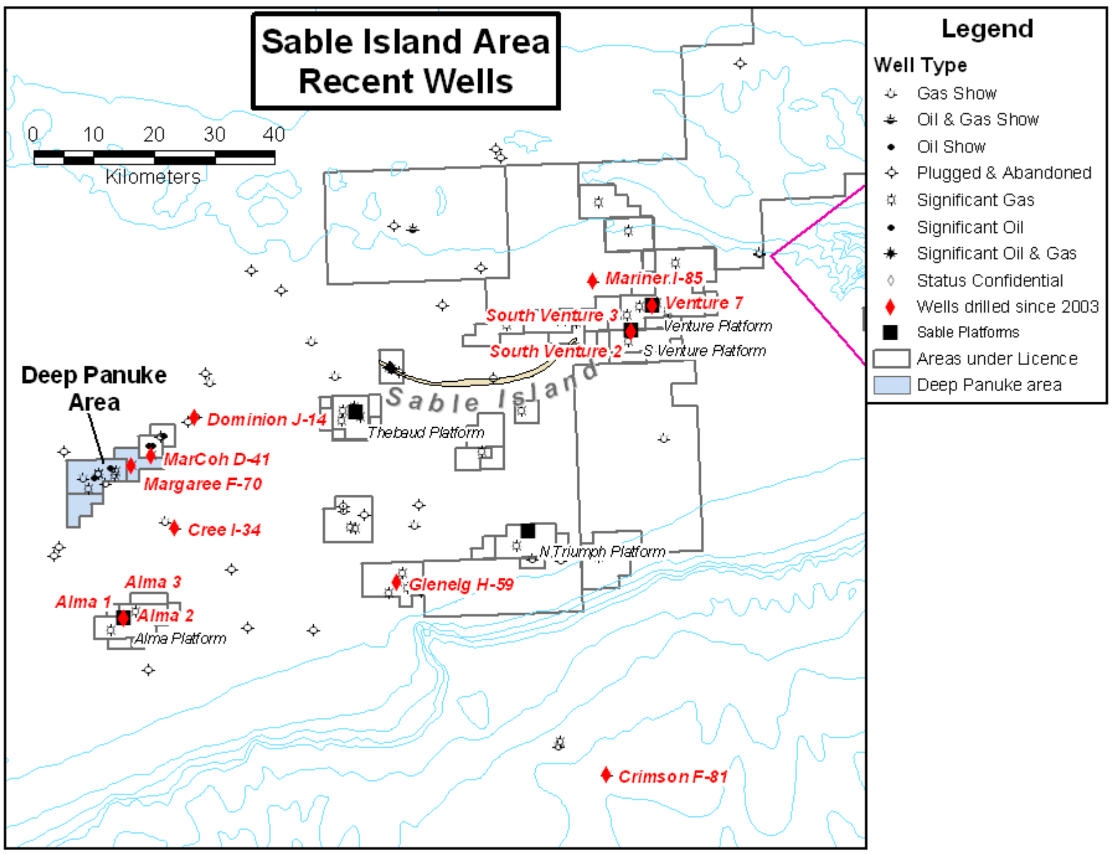


Figure 1: Offshore Oil and Gas Activity in the Vicinity of Sable Island.
(*Courtesy of the Canada-Nova Scotia Offshore Petroleum Board, January, 2009*)

Other sources of emissions in the area include transportation emissions associated with the shipment of personnel and supplies to offshore facilities by helicopter or ship. Passing marine

[4] Duderstadt, K. A. et al., "Photochemical production and loss rates of ozone at Sable Island , Nova Scotia during the North Atlantic Regional Experiment (NARE) 1993 summer intensive.", Journal of Geophysical Research, Vol. 103, No. D11, pp 13531-13555, June 1998.

traffic can also be a source of emissions. Some localized emission sources on Sable Island itself include air traffic to and from the island, diesel-powered electricity supply and waste incineration at the research station.

Figure 2 shows the layout of the Sable Island Station.

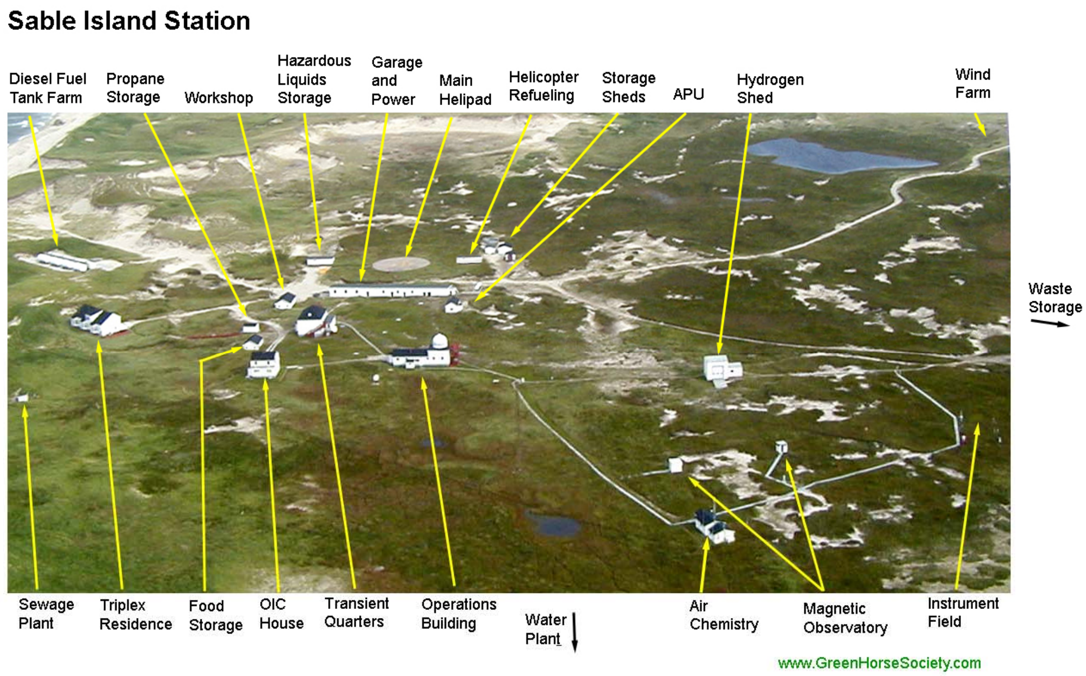


Figure 2: Overview of Sable Island Station Showing the Location of Various Buildings and Associated Equipment. The air monitoring equipment is located in the air chemistry building on the bottom right of the diagram. The view is looking east-southeast. *(Courtesy of Zoe Lucas)*

3.0 STATION SET-UP AND OPERATION

3.1 Set-up

In the fall of 2002, funds provided under the ESRF agreement were used to purchase NO_x, $PM_{2.5}$, and SO_2/H_2S monitors, as well as an air monitoring shelter. Additional funds were used to prepare the site on Sable Island and purchase required equipment. Other monitors (O_3, CH_4, CO and CO_2) and ancillary equipment (satellite communications, data loggers and computers) were provided by other project partners and made ready for installation at Sable Island. Moving this equipment, especially the monitoring shelter, to Sable Island was a challenge, but ExxonMobil made an offer to transport equipment to Sable by offshore supply ship and helicopter when an opportunity arose. Weather and logistical issues delayed the shipment of equipment until the spring of 2003.

In May of 2003, arrangements were made to take the equipment, except for the monitoring shelter, out to Sable Island on the regularly scheduled Coast Guard visit. At this time, the equipment was temporarily set up in an existing building in order to begin data collection. In June of 2003, ExxonMobil had an opportunity to transport the monitoring shelter, and it was moved to the Island as well.

3.2 Air Quality Monitoring Program

As discussed, funds were provided under the ESRF program to monitor NO_x (NO and NO_2), SO_2/H_2S and $PM_{2.5}$. Environment Canada's Atlantic Region added ground-level ozone (O_3) monitoring as a complementary program that is maintained as part of the project. Overviews of these pollutants and of their sources and effects are provided below. Section 3.5.2 provides information on the measurement techniques and instruments used to monitor these pollutants under the Sable Island program.

NO_x refers to nitric oxide (NO) and nitrogen dioxide (NO_2). Emissions of NO_x result primarily from fuel combustion associated with power generation and transportation. There are limited emission sources of NO_x on Sable Island (primarily the diesel generator), although offshore activities and marine traffic in the general vicinity can also contribute to NO_x levels (e.g., exhaust from marine vessels and helicopters, well testing, flaring, venting, etc.). NO_x may also occur naturally at ground level because of lightning or stratospheric intrusion of ozone. Nitrogen dioxide is a concern because it can cause immediate effects to the bronchial region of human respiratory systems as well as longer-term health effects to lungs.[5] Both NO and NO_2 are important components of photochemical smog and can contribute to increased levels of ozone and nitrate particulate.

Hydrogen sulphide gas (H_2S) is naturally occurring in anaerobic soils (the black layer of soil in an inter-tidal zone, for example). H_2S from natural sources is the by-product of respiration of sulphur-reducing bacteria. H_2S can also be a component of natural gas. Its odour is detectable at very low levels (approximately 2 ppbv) and resembles the smell of rotten eggs. H_2S may be released from drilling operations as fugitive emissions during equipment shutdowns or through

[5] Pope, C. Arden et al., "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution.", Journal of the American Medical Association, vol. 287, no 9, pg. 1132-1141, March 2002.

accidental releases. Hydrogen sulphide gas in very high doses can be lethal to humans and long-term exposure at low levels is believed to impair neurological functions.[6]

Sulphur dioxide (SO_2) belongs to a family of sulphur oxide gases (SO_x). It is formed from the sulphur contained in raw materials such as coal, oil and metal-containing ores during combustion and refining processes. SO_2 dissolves in water vapour in the air to form acids and interacts with other gases and particles in the air to form secondary particulate matter. Both SO_2 in its untransformed state and the acid and sulphate particle transformation products of SO_2 can have adverse effects on human health or the environment. SO_2 itself can cause adverse effects on the respiratory systems of humans and animals as well as damage to vegetation. When dissolved by water vapour to form acids, it can again have adverse effects on the respiratory systems of humans and animals, cause damage to vegetation, buildings and materials and contribute to acidification of aquatic and terrestrial ecosystems.[7] When transformed into sulphate particles that are then combined with other compounds in the atmosphere, such as ammonia, SO_2 becomes an important contributor to the secondary formation of fine particulate matter.

Fine particulate matter ($PM_{2.5}$) consists of very small solid or liquid particles (<2.5µm in diameter). $PM_{2.5}$ may be made up of a variety of compounds and come from a variety of sources. On Sable Island, long-range transport of primary or secondary $PM_{2.5}$ is the most likely source. Direct anthropogenic contributions of primary $PM_{2.5}$ can result from residential wood combustion, industrial activities such as mining and pulp and paper manufacturing, and dust from paved and unpaved roads. $PM_{2.5}$ may also be formed in the atmosphere from the interaction of precursor gases (SO_x, NO_x, VOC and NH_3) to form secondary $PM_{2.5}$. Natural sources of $PM_{2.5}$ may include emissions from marine algae or sea salt distributed in the atmosphere from wave action. VOC emissions from conifers may also condense to form particulate. $PM_{2.5}$ is known to have harmful effects on human health and the environment and also contributes to visibility impairment and regional haze. Inhaled $PM_{2.5}$ may end up deep in the lungs where it may cause inefficient exchange of oxygen and inflammation of the alveoli. Depending on the nature of the particulate, it may also displace oxygen in the blood or enter the blood stream and increase the viscosity of blood, thereby constricting passage through the blood vessels. Obviously, $PM_{2.5}$ is of great concern for human health, especially for people with heart disease and lung diseases, such as asthma and bronchitis.[8]

Ground-level ozone refers to the molecules of three oxygen atoms (O_3) found in the troposphere. Ozone is normally found in the stratosphere where it provides a shield protecting humans and other living organisms from excessive ultraviolet radiation. Ground-level ozone, however, is not desirable because it is a highly reactive gas that damages lung tissue, is harmful to plant tissue, and accelerates the degradation of some synthetic materials.[9] The presence of ground-level ozone may be attributable to stratospheric ozone intrusions or lightning events, but it is mainly formed from the reaction of anthropogenic precursors, namely NO_x and volatile organic compounds (VOCs), in the presence of sunlight. As with $PM_{2.5}$, much of the ozone on Sable Island results

[6] Kaye H. Kilburn, M.D., "Exposure to Reduced Sulfur Gases Impairs Neurobehavioral Function." Southern Medical Journal, Vol. 90, No. 10, pp 997-1006, October 1997.

[7] Canadian Acid Deposition Science Assessment. Environment Canada, 2005. Available at http://www.msc-smc.ec.gc.ca/saib/acid/assessment2004/index_e.html.

[8] Pope, C. Arden et al., "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution." Journal of the American Medical Association, Vol. 287, No. 9, pp 1132-1141, March 2002.

[9] National Ambient Air Quality Objectives for Ground-level Ozone: Science Assessment Document. Health Canada and Environment Canada, July 1999.

from long-range transport of pollutants from source regions in the US and the Great Lakes Region.

3.3 Greenhouse Gas Monitoring Program

Environment Canada's Air Quality Research Branch decided to take advantage of the Sable Air Monitoring Program to implement a greenhouse gas (GHG) monitoring program on the island. Analyzers monitor for CO, CO_2, and CH_4. Long-term trend analysis will help determine changes in overall GHG levels and any resulting implications for climate change. CO concentrations can also be a valuable marker for anthropogenic sources of pollution. However, because of the preliminary nature of the data, CO data were not considered part of this report.

Sable Island is also one of five Canadian baseline stations measuring greenhouse gas concentrations under the Global Atmospheric Watch (GAW), a monitoring program of the World Meteorological Organization (WMO). The GAW monitoring program includes a co-ordinated global network of observing stations along with supporting facilities. GAW provides data for scientific assessments and for early warnings of changes in the chemical composition and related physical characteristics of the atmosphere that may have adverse effects on our environment. Monitoring priorities for the overall GAW include greenhouse gases for possible climate change, ozone and ultraviolet radiation for both climate and biological concerns, and certain reactive gases and the chemistry of precipitation for a multitude of roles in pollution chemistry.

The existence of the GHG program and the Greenhouse Gas Measurement Lab in Downsview, Ontario, has allowed the Sable Island Air Monitoring Program to take advantage of communications and satellite equipment used to collect and transfer data from the island (see Section 3.5). This has significantly reduced the costs associated with the set-up and operation of the air quality monitoring program on Sable Island.

3.4 Maintenance and Support of the Monitoring Program

Operating and maintaining complex monitoring equipment in a remote area such as Sable Island is a challenge. In order to maintain the integrity of the data, the monitors need regular maintenance and calibration, as well as occasional troubleshooting and repairs when things break down. Trips to Sable Island are expensive and must be arranged with consideration given to available flight opportunities and weather events which can delay arrivals and departures from the island for days at a time. As well, the need for satellite communications limited opportunities to carry out remote troubleshooting. Participants in the program have worked to find the most reasonable maintenance and operating procedures to take these difficulties into account.

During the 2003−2006 period, the monitoring technologist for Nova Scotia Environment carried out most of the maintenance for the project and scheduled two regular visits annually, of about four days each, to the island. Each visit included standard cleaning, inspection, tuning and calibrations as well as any required repairs. The spring visit also included a preventive maintenance overhaul and the change-out of various instrument components. During this time period, visits occurred in June and December, but they will be changed to April and October to take advantage of better weather. To minimize costs, attempts were made to schedule these trips with existing flights (i.e., food flights) to the island. Poor weather washed out the runway on one of the earlier visits to the island, leaving the technologist stranded for a number of extra days. To guard against this happening again, more care is taken to identify upcoming weather conditions that might interfere with the trip, and arrangements are also made to use a helicopter if required to bring the technologist off the island.

Additional support was provided by personnel who staff Sable Island on a permanent basis. The monitoring station was visited by staff on a twice-daily basis to verify proper instrument operation and change filters as needed. They also notified the technologist if any of the instruments exhibited an alarm state and provided on-site assistance with troubleshooting. Support by Sable Island staff has helped to resolve several minor problems, with instructions transmitted by telephone or email.

Despite these best efforts, there were still situations where a monitor broke down unexpectedly and repairs required either a special part and/or the skills of the monitoring technician. In each case, the value of any lost data had to be balanced against the feasibility and cost of a special trip to the island.

3.5 Communications and Data Transfer

3.5.1 Data Management[10]

During the 2003−2006 period, Environment Canada's Greenhouse Gas Measurement Lab (GGML) in Downsview, Ontario, provided the programming for the data loggers and the telemetry expertise to retrieve the data from Sable Island. The monitoring instruments were connected to two Campbell Scientific data loggers. Information from the data loggers was automatically recovered by the GGML. The data logger clocks were all set to Greenwich Mean Time (GMT) and kept in sync with the National Research Council (NRC) through a host computer. Data were retrieved from Sable Island by servers in Downsview using file transfer protocol (FTP). The data were collected in GMT and provided to both MSC Atlantic (www.atl.ec.gc.ca) and Nova Scotia Environment (www.gov.ns.ca) every hour. Downsview reformatted the data for each group. Some internal processing was also done by Downsview (i.e., GMT).

Data sent to MSC Atlantic for AIRNow were reformatted to their specifications and reported in GMT.

Data sent to Nova Scotia Environment was reformatted according to their specifications and reported in GMT-4 hours. Every hour, a file for each pollutant measured (O_3, SO_2, H_2S, NOx, NO, NO_2 and $PM_{2.5}$) was sent to Nova Scotia Environment's FTP server. Each file contained date and time stamps and the corresponding concentration for each pollutant for the past 24-hours. Nova Scotia Environment's ambient air data management server polled the FTP site every hour and added the data to their database. The technologist responsible for the program at Nova Scotia Environment also carried out the QA/QC of the data provided.

From 2003 to 2006, communication between Sable Island and Downsview and between Downsview and Nova Scotia Environment broke down or was delayed at times. These communication difficulties resulted in gaps in the database maintained by Nova Scotia Environment. One approach to filling these gaps was to periodically update the database with a bulk file provided by Downsview. Though there were time delays with this process, it did result in the creation of a complete historical database. As such, this process was done bi-annually, following each maintenance visit to Sable Island.

[10] Note that the procedures outlined in this section describe the data management procedures during the 2003−2006 time period. These procedures changed significantly as of October 2008.

The third-party nature of the data supply to Nova Scotia Environment caused quality assurance and quality control challenges. While data were provided to Nova Scotia Environment on an hourly basis, the technologist did not have remote access to the equipment or regular access to operating parameters. This made it difficult to identify and troubleshoot data issues and equipment problems. In the beginning, the technologist was provided access to weekly QA/QC charts (see Figure 4), but changing security protocols within Environment Canada interrupted this access part way through the project.

Early in the project, a power supply failed for the data loggers and several months of data were lost. Some of the data were retrieved from an internal data logger in the $PM_{2.5}$ monitor, but data for the gas analyzers (O_3, H_2S, SO_2 and NO_x) were not recovered. In 2005, a communications failure resulted in several weeks of lost data and necessary instrument servicing also resulted in some data being unavailable for an extended period. In 2006, there appears to have been an instrument drift beginning in June that resulted in artificially inflated values for the H_2S and SO_2 data for the remainder of that year.

Since the Sable Island Air Monitoring Program began, alternative methods for gathering and managing data from the monitoring station have been investigated and implemented. A new data management system was installed on Sable Island in October 2008. This new system includes hardware (an industrial computer, uninterrupted power supply and surge protector) and software (EnviDAS© by Envitech). The new system collects digital monitoring and diagnostic data from the instruments for O_3, $PM_{2.5}$, NOx, SO_2 and H_2S on a continuous basis. The EnviDAS© software also executes automatic zero/spans daily. Every hour, data are collected from the data logger by a central polling server and stored in a central database located in Halifax. Connection with the Island is via satellite and has been reliable. In addition, air quality monitoring staff in Halifax have remote access to the data logger on the Island and can view and make changes to settings. These changes should significantly reduce the data management problems that affected the Sable Air Monitoring Program in its first years.

3.5.2 Instruments

Information on the instruments used to measure each of the pollutants under the program is provided in Table 1 below. Note that these instruments meet or exceed the standards set out under the National Air Pollution Surveillance (NAPS) network protocols. The operating parameters are important to note when considering the data. Instrument settings can have a significant impact on how data are calculated by the analyzers' CPU. The details of each instrument are provided in Appendix D for scrutiny by anyone using the data. A photograph of the monitoring instruments and analyzers at the station on Sable Island is included in Figure 3.

Some problems have been encountered with the performance and upkeep of monitoring equipment in this remote marine environment. For example, the inlet tube for the BAM monitor became extensively corroded and dielectric grease needed to be applied. In addition, the highly corrosive environment resulted in electrolysis between the board connector strip and the back panel of the BAM monitor. The NO_x analyzer also experienced a circuit board failure and was out of service for a period of time.

These problems have occurred despite assurances that these particular types of monitors had run effectively in remote, high-humidity marine environments. As a result, there may be a need for more frequent repairs and/or replacement of the monitors in the future.

Table 1: Measurement Instruments for Pollutants in the Sable Island Air Monitoring Program

Pollutant	Measurement Instrument	Measurement Frequency	Units	Comments
Fine Particulate ($PM_{2.5}$)	MetOne® Beta Attenuation Monitor (BAM)	Set to "Early Cycle" to accommodate external re-setting of the clock, data for the previous hour (50-minute sample) are output to the data logger during the last 5 minutes of the hour.	µg/m^3	The monitor was purchased for this project. An external data logger was used to store the BAM data and to synchronize the BAM's clock. A comprehensive data file was also downloaded from the internal data logger during visits by the technologist.
Sulphur Dioxide/Hydrogen Sulphide (SO_2/H_2S)	Teledyne® Advanced Pollution Instrumentation (API) Model 101A	Continuous measurements are read and stored every five minutes at the data logger. One-hour averages are reported.	ppbv	The monitor was purchased for this project. The analyzer switches between measuring SO_2 on even-hours to measuring H_2S on odd-hours. The instrument often did not switch at exactly the top of the hour so that the hourly averages were somewhat biased.
Nitrogen Oxides (NO_x)	Teledyne® Advanced Pollution Instrumentation (API) Model 200A	Continuous measurements are read and stored every five minutes at the data logger. One-hour averages are reported.	ppbv	The monitor was purchased for this project. A feasible method of direct measurements of NO_2 does not exist for ambient monitors. Therefore, the NO_x analyzer measures the chemiluminescence emitted from the NO and ozone (O_3) reaction as a surrogate.
Ozone (O_3)	Thermo Electron Corporation Environmental Instruments (TEI) Model 49C analyzer	Continuous measurements are read and stored every five minutes at the data logger. One-hour averages are reported.	ppbv	This instrument is provided by the Meteorological Service of Canada (MSC), Atlantic, and was in service in Newfoundland where it had ingested water. A substantial number of repairs were performed by Nova Scotia Environment to bring the instrument to usable condition; so this instrument was not installed until later in 2003.

Source: McPherson, 2005

Figure 3: Calibration Equipment and Gas Analyzers at the Sable Island Station During a Service Session
(L-R): TEI Ozone analyzer (*bottom*), Environics 100 multi-gas calibrator (*top*), API NO_x analyzer, API H_2S/SO_2 analyzer and BAM $PM_{2.5}$ monitor (*Source: McPherson, 2005*)

3.5.3 QA/QC procedure

As described in Section 3.5.1, data from the monitors were retrieved from Sable Island by Environment Canada labs in Downsview, Ontario, and then sent to the Data Manager responsible for the program at Nova Scotia Environment.

In addition to the data files, QA/QC charts were prepared. This file was reviewed for any anomalous readings that may have indicated an instrument malfunction. A sample plot is provided in Figure 4.

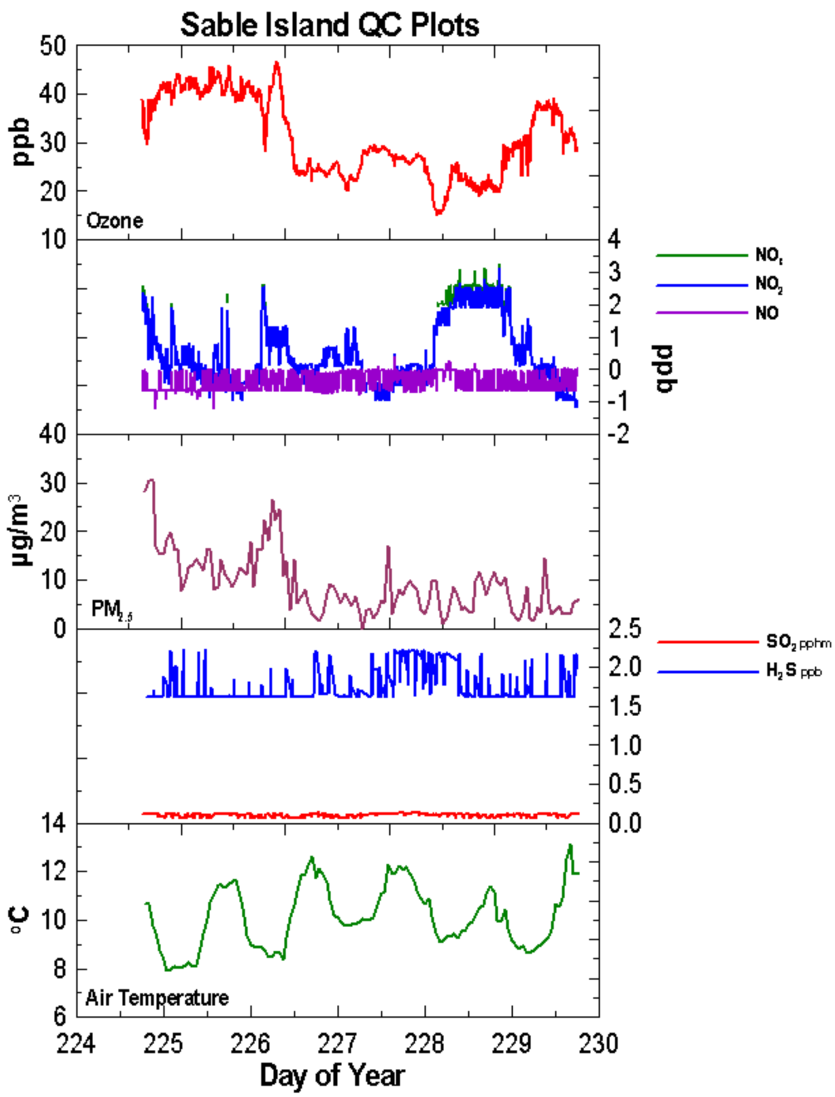


Figure 4: Sample QA/QC Plot for Sable Island Air Monitoring Program Data
(*Source: Environment Canada, 2004*)

It should be noted that the analyzers were programmed to send alarms if any of many possible malfunctions occurred. In addition, the gas analyzers performed a weekly self-test of response against a known concentration of gas. However, the Nova Scotia Environment technologist did not have access to data on the alarms or the results of these self-tests. This was a limitation that prevented immediate recognition of problems, but the records of these results were useful for interpretation of the data.

Technical problems and delays in station set-up resulted in data being available for only a portion of each reporting year. The periods for which data are available for each year are shown in Table 2.

Table 2: Data Completeness for the 2003−2006 Reporting Years

Pollutant	Available Data	Percentage
2003		
$PM_{2.5}$	May 28–September 7 October 20–December 31	45%
Ozone	May 30–June 14 November 27–December 31	13%
H_2S*	November 30–December 31	9%
SO_2*	November 30–December 31	8%
NO_X	May 30–August 26 October 29–December 31	40%
2004		
$PM_{2.5}$	January 1–December 31	92%
Ozone	January 1–December 31	100%
H_2S*	January 1–December 31	91%
SO_2*	January 1–December 31	99%
NO_X	January 1–December 31	85%
2005		
$PM_{2.5}$	January 1–July 27 August 21–October 3	65%
Ozone	January 1–July 27 August 21–December 31	93%
H_2S*	January 1–July 27 August 21–December 31	84%
SO_2*	January 1–July 27 August 21–December 31	92%
NO_X	January 1–February 5, April 17–July 26, August 20–December 31	67%
2006		
$PM_{2.5}$	March 3–December 26	76%
Ozone	January 1–December 31	98%
H_2S*	January 1–May 31	38%
SO_2*	January 1–May 31	41%
NO_X	January 1–December 31	96%

** SO_2 and H_2S measurements are recorded every other hour; other pollutants are recorded hourly.*

3.6 Reporting

Following quality assurance and quality control procedures, Sable Island NO_x, $PM_{2.5}$ and ozone data are reported to the NAPS network on an annual basis by Nova Scotia Environment.[11] MSC Atlantic provides near real-time ozone and $PM_{2.5}$ data to the AIRNow program to be included in its real-time mapping program (see http://airnow.gov/index.cfm?action=airnow.canadamaps). The data are also available upon request to researchers, provided permission is granted by all project partners.

[11] SO_2 data from Sable Island are not reported to NAPS at this time since the data are collected every second hour and hence do not comply with NAPS protocols.

The NAPS network consists of numerous ambient air monitoring sites across the country and is managed jointly by Environment Canada and the provinces and territories. The objectives of the NAPS network are to

- determine the nature and extent of air pollutants;
- provide data for research including the effects of air pollution on health;
- determine trends and predict emerging issues;
- verify estimates of emissions and provide a basis for issue management legislation and international agreements; and
- assess the effect of pollutants from local industry and mobile sources on nearby communities.

The AIRNow Monitoring and Information Network is managed and operated by the United States Environmental Protection Agency. It provides forecast and current condition information on two major air pollutants (O_3 and $PM_{2.5}$) for areas in the continental US and parts of Canada (including the Atlantic Region).

NAPS data from Sable Island are also made available to the Surveillance of Atmospheric Change in Canada (SACC) Network[12] for its research. The goals of the SACC network are to

- provide long-term, high-quality observations of atmospheric composition and radiation at locations representative of major atmospheric regimes (and geopolitical regions) across Canada; and
- serve as a national facility that maintains standards, provides expertise, serves as a reference network for monitoring and research studies of other jurisdictions and universities and fulfils international monitoring commitments.

The Atlantic Region has one full SACC site in Kejimkujik National Park. Sable Island is designated an "associate" SACC site. SACC sites are chosen based on their potential for longevity, suitable location, QA/QC procedures and data archiving.

In addition to contributing to national and international monitoring networks, data from the Sable Island project are also useful in the validation of air quality models. The Canadian Hemispheric and Regional Ozone and NOx System (CHRONOS) and A Unified Regional Air Quality Modelling System (AURAMS) are two models currently used to forecast air quality in Canada. Data from the Sable $PM_{2.5}$ monitor were used to verify ambient levels of $PM_{2.5}$ predicted by the two models during a period of elevated $PM_{2.5}$ levels in February 2005. Ongoing data collection at Sable Island will continue to help validate and refine these air quality models and improve air quality forecasting in the Atlantic Region. Measurements on Sable Island will also help to quantify the contribution of naturally occurring sea-salt aerosols to fine particulate concentrations in coastal environments.

[12] Formerly known as the Canadian Climate and Radiation (CORE) network

4.0 RESULTS

4.1 Data Summary

4.1.1 $PM_{2.5}$ Results

Canada currently has a Canada-wide Standard for $PM_{2.5}$ and a National Ambient Air Quality Objective (NAAQO) for Total Suspended Particulate (TSP). Nova Scotia has adopted the NAAQO in its Air Quality Regulations and is also a party to the CWS agreement. In 2005, the World Health Organization published its recommendations on ambient air quality guidelines for $PM_{2.5}$. These various standards are listed in Table 3.

Table 3: Current Ambient Air Quality Objectives for Particulate Matter

Standard/Objective	**24-hour (µg/m^3)**	**Annual Average (µg/m^3)**
National Ambient Air Quality Objectives for Total Suspended Particulate	120 (acceptable)	60 (desirable) 70 (acceptable)
Canada-wide Standard for $PM_{2.5}$	30	--
Nova Scotia Air Quality Regulations for Total Suspended Particulate	120	70
World Health Organization (WHO) Ambient Air Quality Guidelines for $PM_{2.5}$	25	10

The Canada-wide Standard for $PM_{2.5}$ is 30 µg/m^3 averaged over 24-hour periods, to be achieved by 2010. Achievement is to be based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years. Only the year 2004 meets the standard for completeness under the CWS criteria. Irrespective of the lack of completeness, an analysis of the existing data shows that the CWS appears to have been met for the three-year window of 2004 to 2006, at 19.3 µg/m^3.

Because there are no NAAQO for $PM_{2.5}$, data from the Sable Island $PM_{2.5}$ monitor were compared to the World Health Organization Ambient Air Quality Guidelines. In 2003 (June−December period), nine daily averages exceeded the WHO 24-hour Guideline of 25µg/m^3. There was one exceedance in each of the 2004 and 2005 reporting years. In 2006, there were three 24-hour averages above the WHO Guideline. There were also several high hourly measurements in 2006, including the annual high of 219 µg/m^3. The World Health Organization annual average for $PM_{2.5}$ was exceeded in 2003 and values were close to this annual average for both 2005 and 2006.

Concentrations at Sable Island were well below the 24-hour and annual concentrations for Total Suspended Particulate established by NAAQO and the Nova Scotia Air Quality Regulations.

The annual averages, maximum 1-hour concentrations and maximum daily averages for $PM_{2.5}$ from 2003 to 2006 are shown in Table 4. The numbers of days in each year above the WHO Guideline are also listed.

Table 4: $PM_{2.5}$ Results for 2003 to 2006 – Annual Averages, Daily and Hourly Maximums per Year and the Number of Days Above the World Health Organization 24-hour Guideline.

Year	Annual Average** µg/m³	Hourly Measurements	24-hour Average	
		Annual High µg/m³	Annual High µg/m³	# Days Above WHO Guideline
2003*	10.7	68	46	9
2004	7.7	85	28	1
2005	9.8	48	29	1
2006	9.0	219	41	3

* Measurements from June to December.
**Average of Hourly Measurements

The frequency distributions of $PM_{2.5}$ daily averages and daily maxima are shown in Figure 5 and Figure 6, respectively. Generally, the distributions show that daily $PM_{2.5}$ averages are clustered at levels situated at about half of the WHO 24-hour Guideline, across all the years. Very few higher maximum concentrations were recorded. The daily maxima distribution shows fewer than forty days each year with maxima above 25µg/m³, with the exception of 2006. The majority of days recorded show 1-hour maximums in the range of 5 to 20 µg/m³ for all of the years shown.

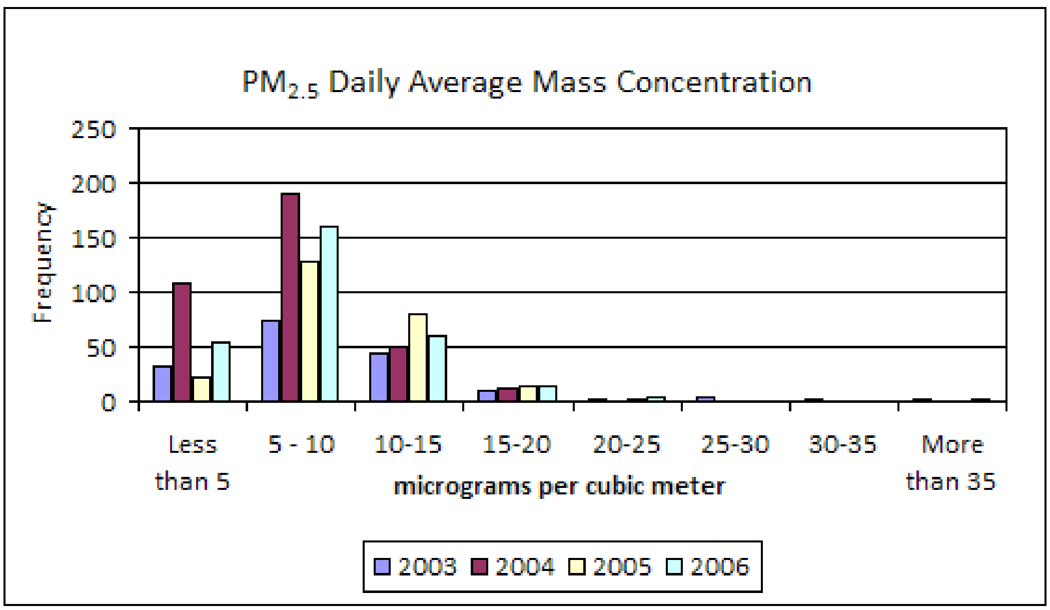


Figure 5: Frequency Distributions for Sable Island $PM_{2.5}$ Daily Average Mass Concentration for Part of 2003 (June to December) and 2004 through 2006

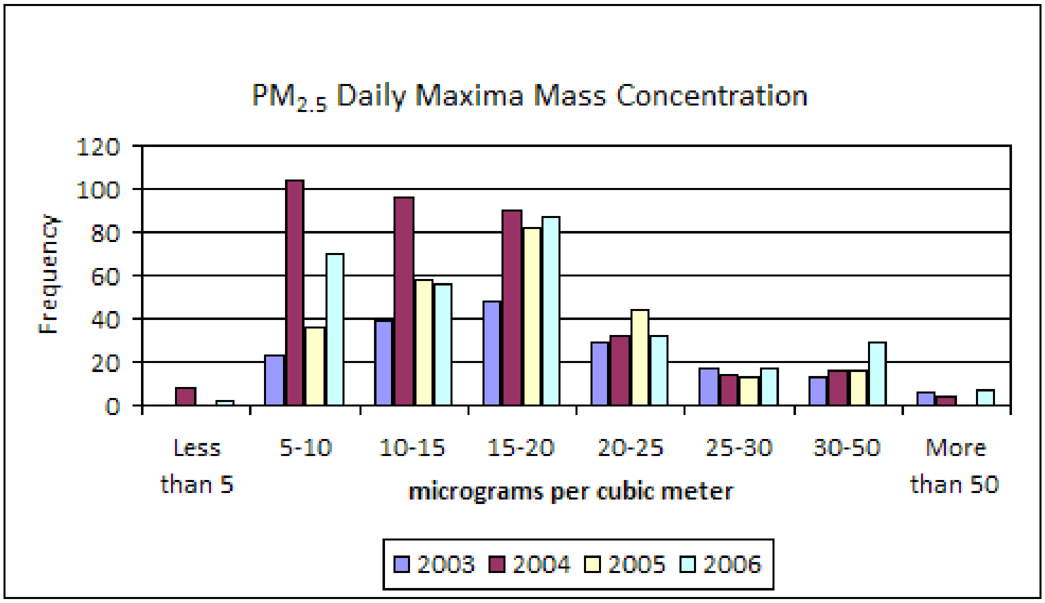


Figure 6: Frequency Distributions for Sable Island $PM_{2.5}$ Daily Maxima for Part of 2003 (June to December) and 2004 through 2006

Figure 7 shows the frequency of wind direction for Sable Island. Figure 8 provides an analysis of wind direction and $PM_{2.5}$ concentrations recorded on Sable Island over the years from 2003 to 2006. The highest $PM_{2.5}$ concentrations were recorded in the southwest direction (250 degrees), which coincides with the location of the Thebaud offshore platform. However, this is also the prevailing wind direction for the site and so the elevated levels recorded could also be due to other influences, including those associated with the transboundary flow of pollutants from onshore areas.

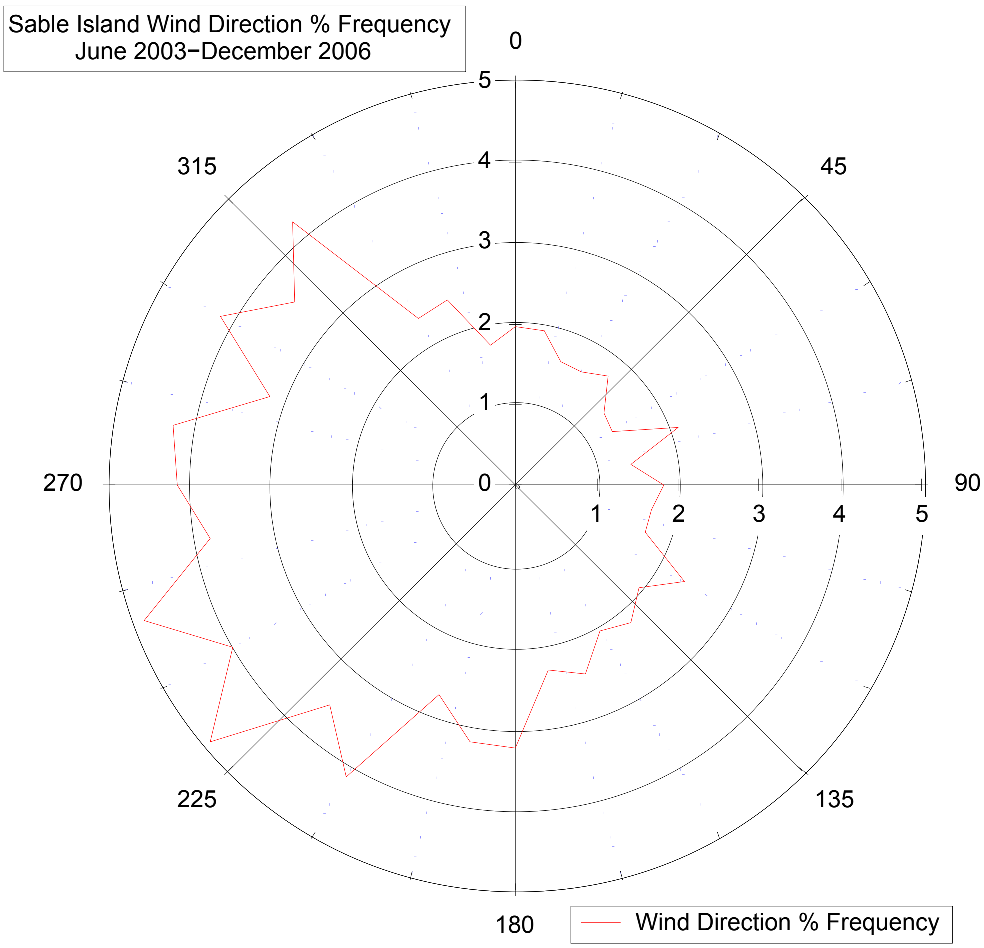


Figure 7: Sable Island Wind Direction Frequency, June 2003−December 2006
Calm winds were observed 1.2% of the time. The most dominant wind direction was from the southwest.

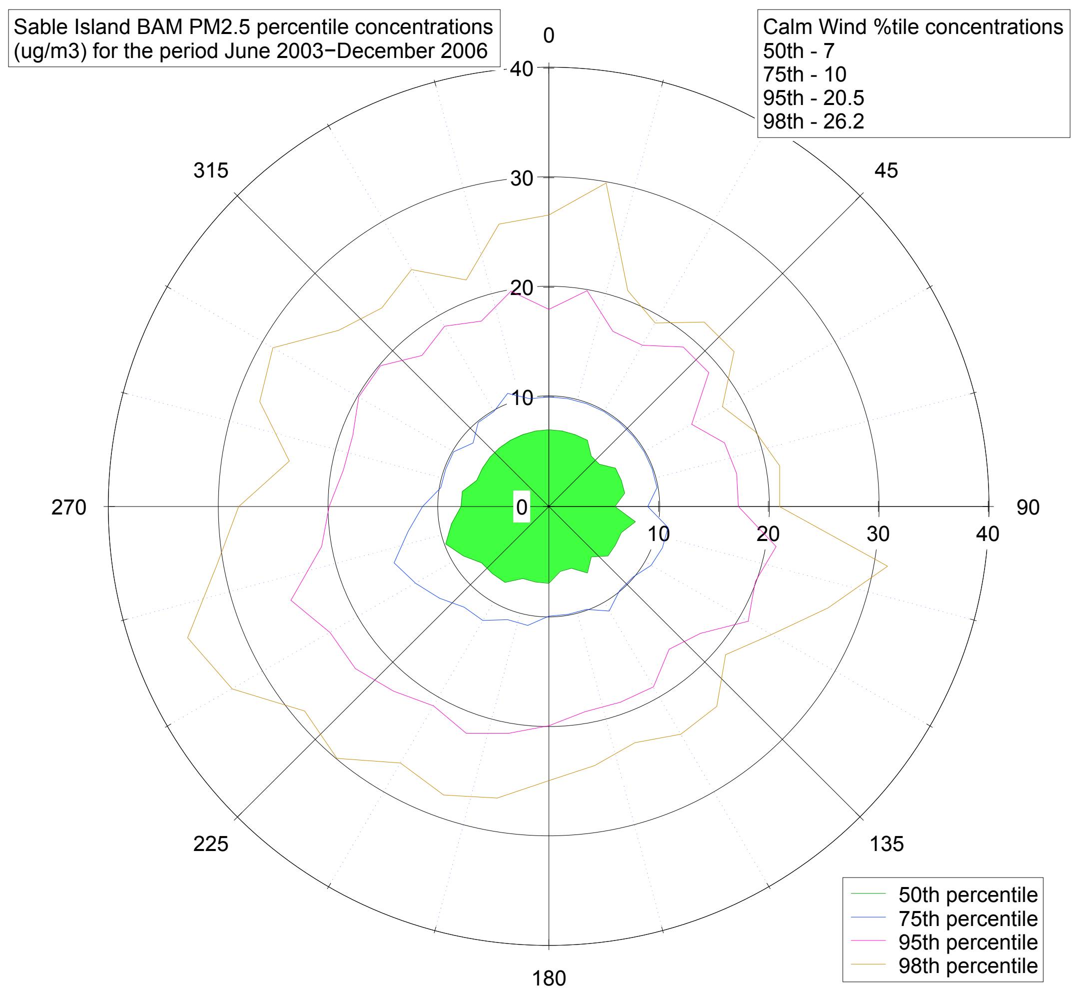


Figure 8: Plot of the Sable Island $PM_{2.5}$ (BAM) Percentile Concentrations by Wind Direction for the June 2003–December 2006 Period
Winds from 010 degrees, 100 degrees and 250 degrees appear as the most prominent directions for elevated concentrations of fine particles at the 98th percentile.

4.1.2 Ground-level Ozone Results

Canada currently has a Canada-wide Standard (CWS) and National Ambient Air Quality Objectives (NAAQO) for Ground-Level Ozone. Nova Scotia has adopted the 1-hour Maximum NAAQO level in its Air Quality Regulations and is also a party to the CWS agreement. In 2005, the World Health Organization published its recommendations on ambient air quality guidelines for ozone. These various standards are listed in Table 5.

Table 5: Current Ambient Air Quality Objectives for Ground-level Ozone

Standard/Objective	1-Hour Average (ppb)	8-Hour Average (ppb)	24-Hour Average (ppb)	Annual Average (ppb)
National Ambient Air Quality Objectives	51 (desirable) 82 (acceptable)	--	15 (desirable) 25 (acceptable)	15 (acceptable)
Canada-wide Standard	--	65	--	--
Nova Scotia Air Quality Regulations	82	--	--	--
World Health Organization (WHO) Ambient Air Quality Guidelines	--	50	--	--

The Canada-wide Standard for Ground-level Ozone (hereafter referred to as ozone) is 65 ppb averaged over 8-hour periods, to be achieved by 2010. Achievement is to be based on the 4th highest measurement annually averaged over 3 consecutive years. Following the procedure provided by the *Guidance Document on Achievement Determination* (CCME, 2007), the data for 2004 through 2006 meet the completeness standard and the calculated 3-year average was 56.3 ppb, which meets the standard.

The yearly maximum concentrations, maximum daily averages, maximum 8-hour averages and annual averages for ozone are shown in Table 6 below, with the NAAQO exceedances in Table 7. Although the 1-hour acceptable NAAQO for ozone was not exceeded from 2003 to 2006, there were exceedances of the 1-hour desirable and the 24-hour NAAQO over all four years. The annual averages all exceeded the maximum acceptable level of 15 ppb. All four years also had exceedances of the World Health Organization (WHO) 8-hour guideline for ozone, as shown in Table 7. However, it should be noted that many sites in the northern mid-latitudes routinely exceed the NAAQO 24-hour and annual average concentrations for ozone as well as the WHO 8-hour average. In comparison to other sites in these latitudes, the mean concentrations of ozone found at Sable Island are not significantly higher than concentrations recorded at nearly pristine sites.[13]

Table 6: Ozone Results for 2003 to 2006 – Maximum Measurements and Annual Averages

Year	Maximum Hourly (ppb)	Maximum Daily Average (ppb)	Maximum 8-Hour Average (ppb)	Annual Average**(ppb)
2003*	74	56	65.5	33.5
2004	62	46	55.5	29.6
2005	60	46	55.8	27.0
2006	61	55	60.0	31.2

* Approximately 1.5 months of measurements
** Average of hourly measurements

[13] David Parrish, pers. com., external review comments, January 2009

Table 7: Ozone Results for 2003 to 2006 – Number of Exceedances of National Ambient Air Quality Objectives (NAAQO) and the World Health Organization (WHO) Guideline

Level	**NAAQO Desirable Levels**		**NAAQO Acceptable Level****	**WHO Guideline**
Year	**1 hour (>51 ppb)**	**24 hour (>15 ppb)**	**24 hour (>25 ppb)**	**8 hour (>50 ppb)**
2003*	43	51	47	52
2004	45	364	274	39
2005	17	337	209	13
2006	112	359	272	142

* Approximately 1.5 months of measurements
**There were no exceedances of the NAAQO 1-hour acceptable level of 82 ppb.

The frequency distributions of ozone daily averages and daily maxima are shown in Figure 9 and Figure 10, respectively.

An examination of the frequency distributions shows higher daily averages in 2006 than in other years, though a comparison with 2003 is difficult because only 1.5 months of data are available. The daily maximums are also higher in 2006 than in the other years. The bins used in Figures 9 and 10 correspond to the NAAQO. The majority of daily averages fall above the maximum acceptable 24-hour level of 25 ppbv, with very few values below the 24-hour maximum desirable level of 15 ppbv. This seems to indicate elevated background levels of ozone, with very few episodes of high concentration. The annual average would confirm this because all years exceeded the annual maximum acceptable level of 15 ppbv. Again, however, the NAAQO 24-hour and annual average levels for ozone may be somewhat unrealistic because pristine background sites can record ozone concentrations in excess of these levels.

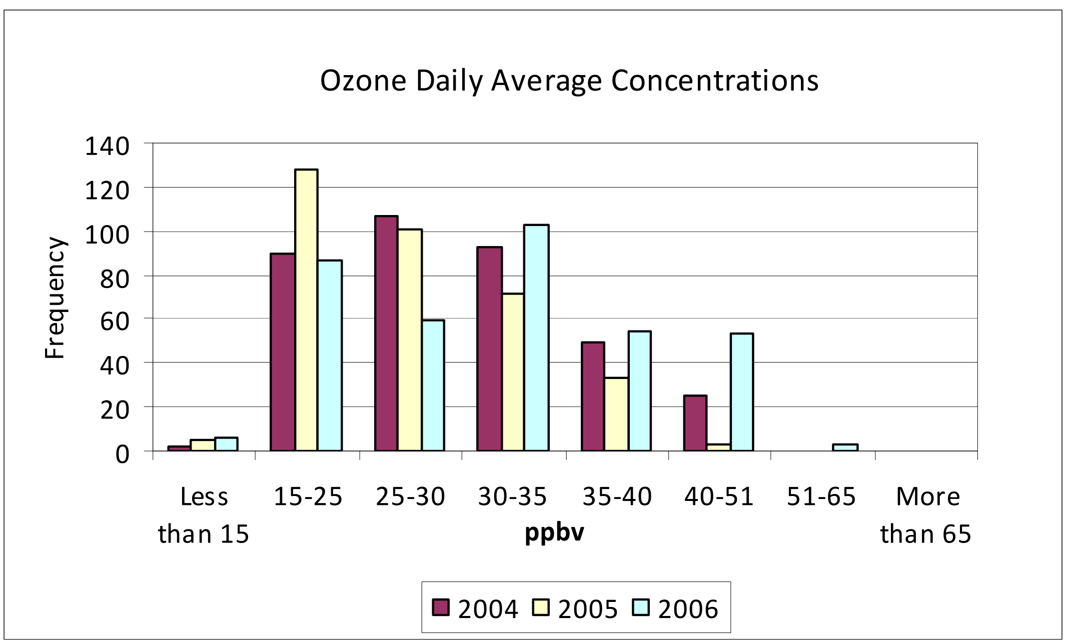


Figure 9: Frequency Distributions for Sable Island Ozone Daily Average Concentrations for 2004, 2005 and January Through May 2006 (2003 not shown because only 1.5 months of data were available)

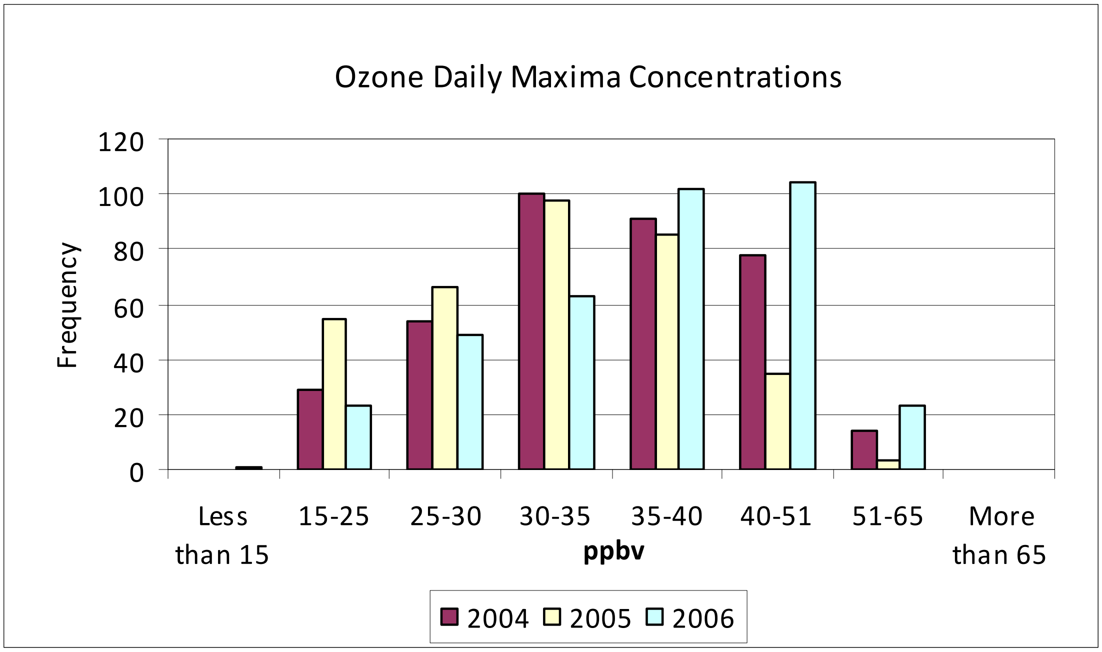


Figure 10: Frequency Distributions for Sable Island Ozone Daily Maxima Concentrations for 2004, 2005, and January Through May 2006 (2003 not shown because only 1.5 months of data were available).

Figure 11 provides an analysis of wind direction and ozone concentrations recorded on Sable Island over the years from 2003 to 2006. Although there is a slight bulge in the SE direction, the figure does not appear to indicate any statistically significant wind directional influence on ozone concentrations from this current analysis.

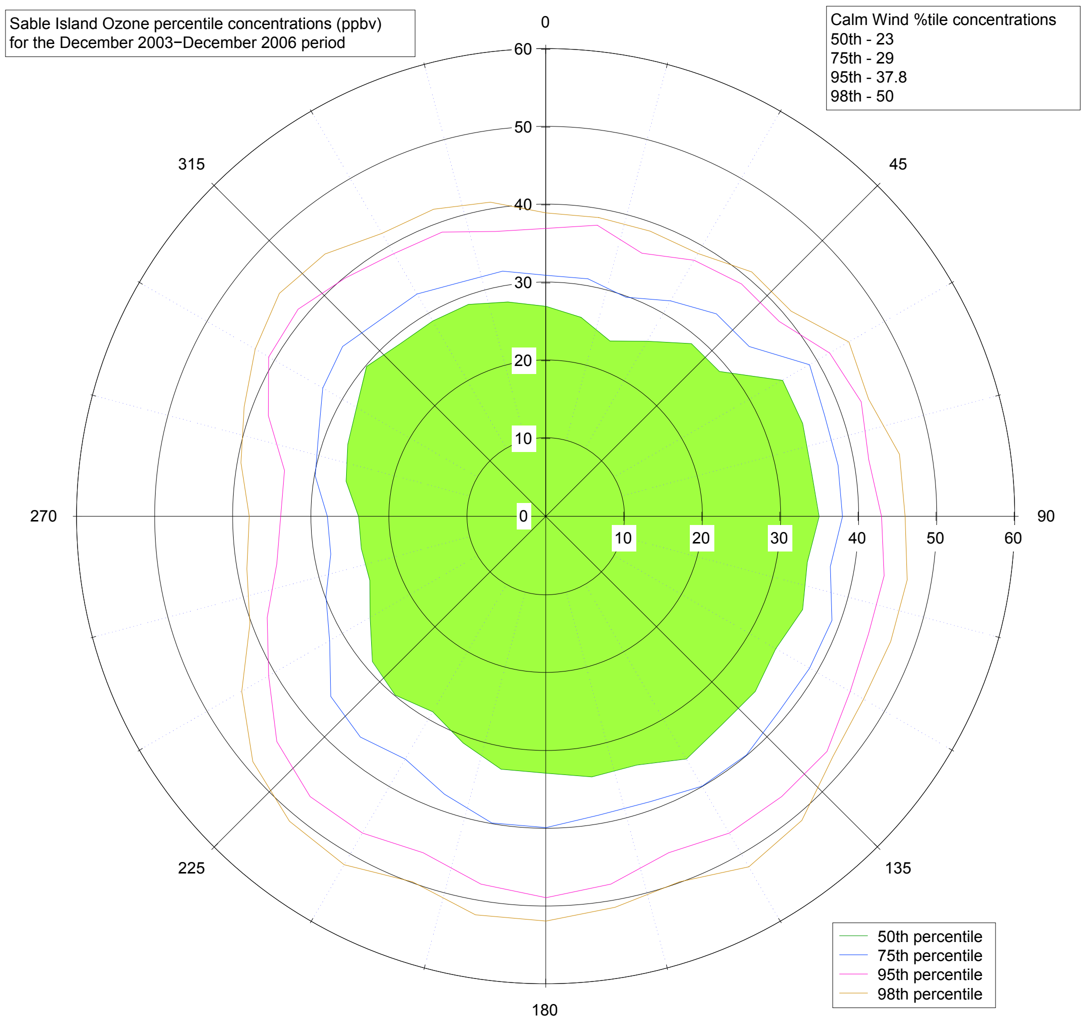


Figure 11: Plot of the Sable Island Ozone Percentile Concentrations (in ppbv) by Wind Direction for the December 2003–December 2006 Period

There does not appear to be any statistically significant wind directional influence on the ozone concentrations from this current analysis.

4.1.3 NOx and NO_2 Results

At the present time, there is no Canada-wide Standard for NOx. The concentrations of NOx and NO_2 on Sable Island were compared to the National Ambient Air Quality Objectives (NAAQO) for nitrogen dioxide. Nova Scotia's Air Quality Regulations set permissible levels of NO_2 equivalent to the NAAQO. Concentrations were also compared to the World Health Organization's Ambient Air Quality Guidelines for nitrogen dioxide. A list of these objectives is shown in Table 8.

Table 8: Current Ambient Air Quality Objectives for Nitrogen Dioxide (NO_2)

Standard/Objective	1-Hour (ppb)	24-Hour (ppb)	Annual Average (ppb)
National Ambient Air Quality Objectives	213 (acceptable)	106 (acceptable)	32 (desirable) 53 (acceptable)
Nova Scotia Air Quality Regulations	213	--	53
World Health Organization Ambient Air Quality Guidelines	105	--	21

The maximum concentrations and maximum daily averages for NOx and NO_2 in each year are shown in Table 9. The maximum values fall well below both the NAAQO and WHO objectives. There were no daily measurements of NOx or NO_2 that exceeded either the 24-hour or the 1-hour maximum levels. No annual averages exceeded any of the annual average objectives. In fact, the concentrations were significantly below any of these levels, as shown in Table 9. Based on this information, NOx and NO_2 do not appear to be a concern in the Sable Island area at the present time.

Table 9: NOx and NO_2 Hourly and Daily Maxima and Annual Average Results for 2003 to 2006

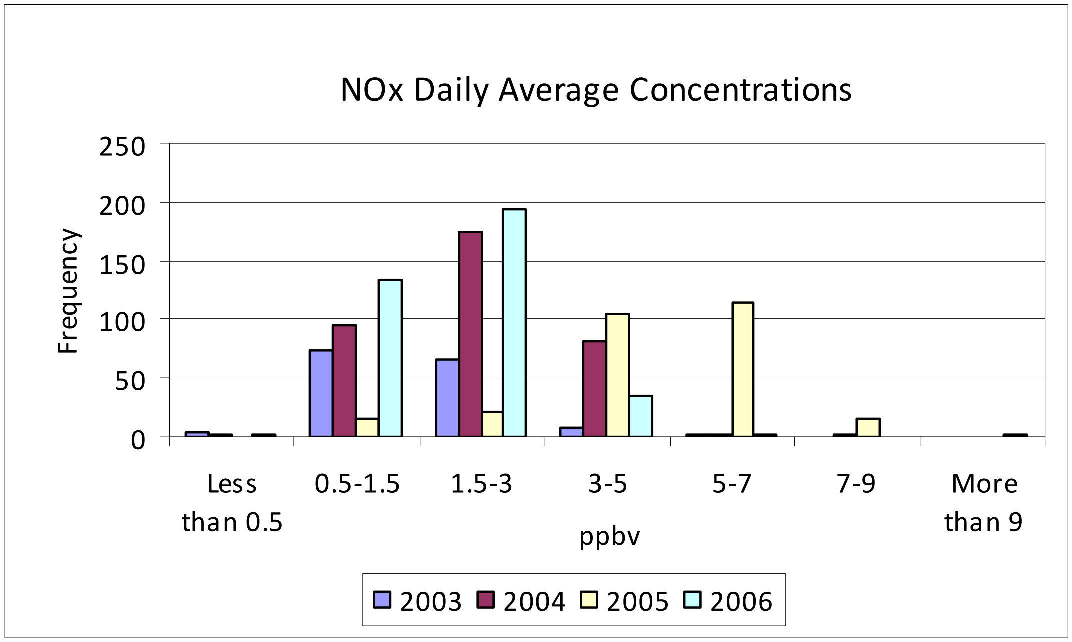
Year	Maximum Hourly (ppbv)		Maximum Daily Average (ppbv)		Annual Average (ppbv)	
	NOx	NO_2	NOx	NO_2	NOx	NO_2
2003*	51	43	7	5	1.7	1.5
2004	30	16	8	7	2.4	1.7
2005	29	13	9	7	4.9	2.6
2006	47	24	10	5	1.9	0.3

*Approximately 5 months of measurements

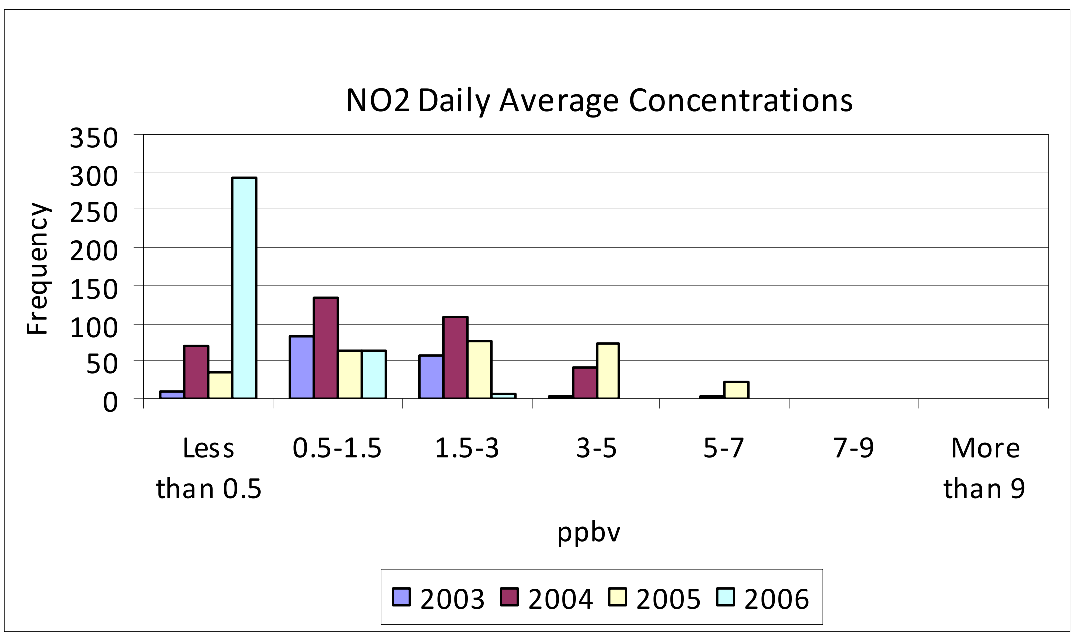
The frequency distributions of nitrogen oxides and nitrogen dioxide daily averages and daily maxima are shown in Figure 12 and Figure 13, respectively.

The daily averages for NOx show no particular pattern over the three years from 2004 to 2006. The reduced number of measurements in 2003 makes a comparison with the other years difficult. The 2005 levels show more days with higher measurements than the other two years. The NO_2 daily averages also show increased frequency of higher concentrations for 2005 versus 2004 and 2006. This conclusion is supported by the higher annual average in 2005 for both substances.

As with the daily averages, the daily maximum concentrations show no pattern across the three years from 2004 to 2006. The daily maximums for both NOx and NO_2 were higher in 2005 than in the other two years.

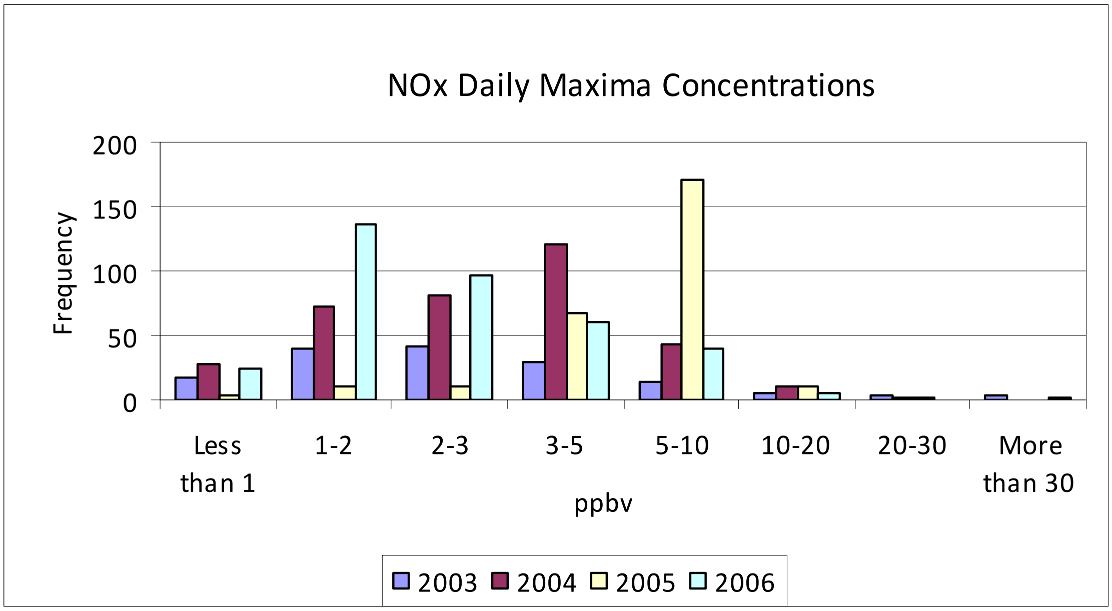


a) Frequency distribution of NOx daily averages

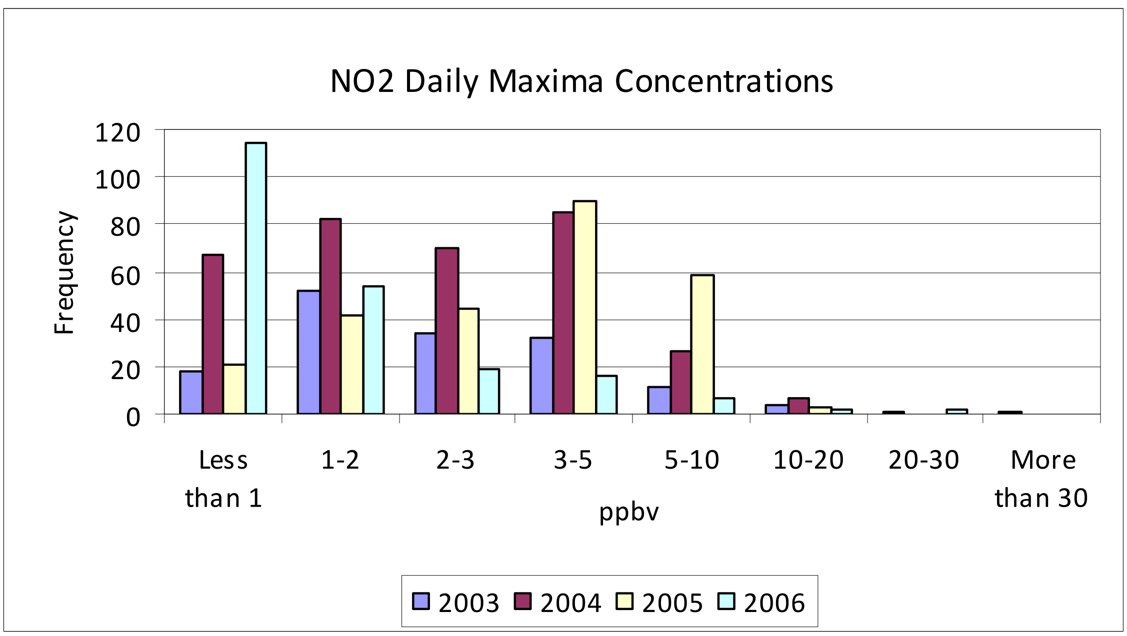


b) Frequency distribution of daily NO_2 daily averages

Figure 12: Frequency Distributions for Sable Island Daily Average Concentrations of (a) NOx and (b) NO2 from 2003 (~5 months of data) to 2006



a) Frequency distribution of NOx daily maxima concentrations



b) Frequency distribution of NO_2 daily maxima concentrations

Figure 13: Frequency Distributions for Sable Island Daily Maxima Concentrations of (a) NOx and (b) NO2 from 2003 (~5 months of data) to 2006

Figure 14 provides an analysis of wind direction and NOx concentrations recorded on Sable Island over the years from 2003 to 2006. The highest NOx concentrations were recorded in the direction of 70−90 degrees, which coincides with the location of the diesel generator on Sable Island as well as the Venture offshore platform and its diesel generators.

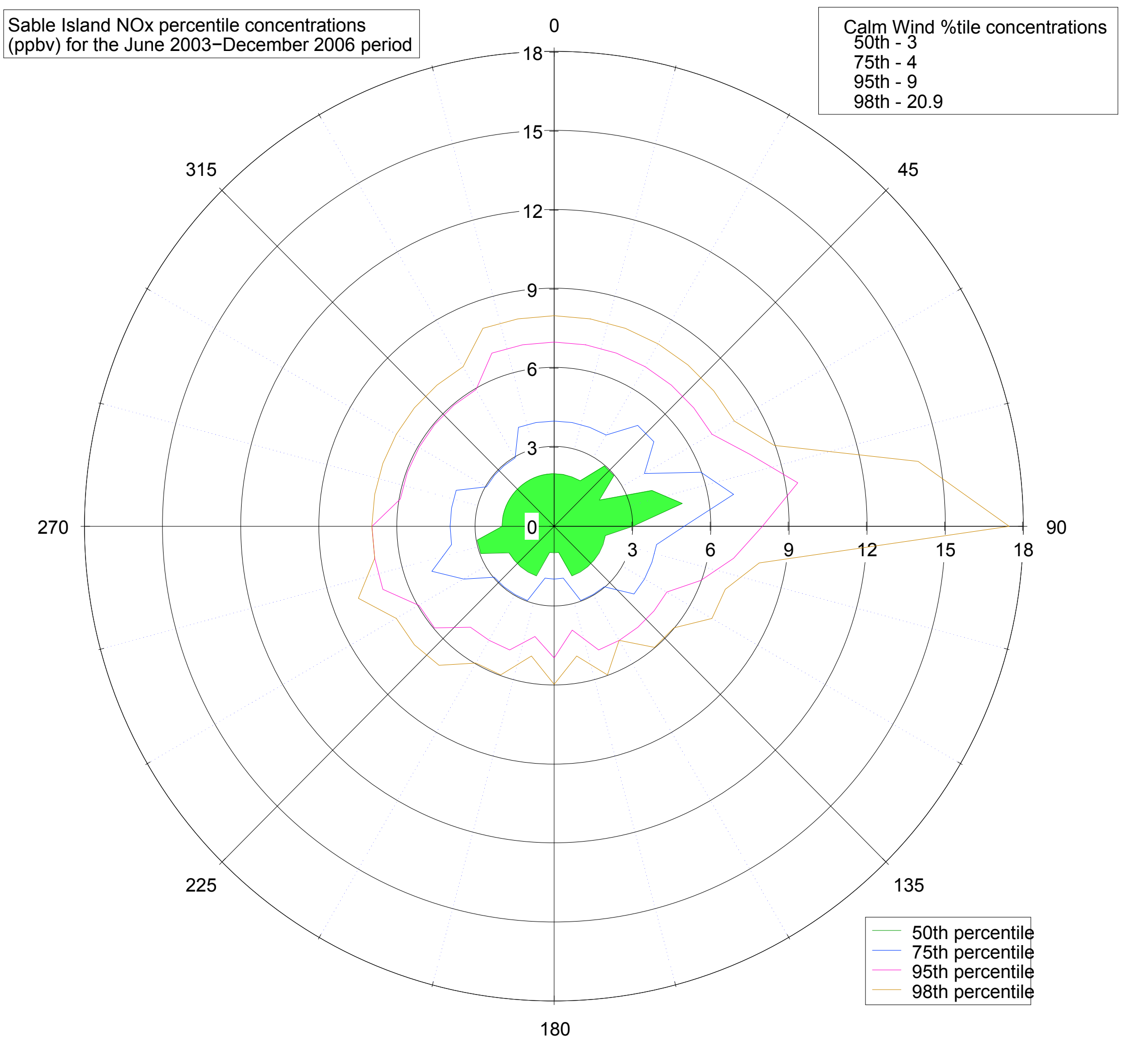


Figure 14: Plot of the Sable Island NOx Percentile Concentrations (in ppbv) by Wind Direction for the June 2003–December 2006 Period
Winds from 070-090 (diesel generators on Sable Island and/or Venture platform) show a very strong signal with a weak signal from 250 degrees (Thebaud production platform).

4.1.4 H_2S Results

As previously discussed, there is only one monitor for both H_2S and SOx. The monitor alternates between the two pollutants and therefore H_2S is reported every other hour. In 2006, there appears to have been an error with the instrument that resulted in a stepwise increase in the measurements beginning in the month of June. For the purposes of this report, data examination for 2006 will examine only measurements from January to the end of May, before this error appears.

There are no Canada-wide Standards or National Ambient Air Quality Objectives for hydrogen sulphide in Canada. Concentrations of hydrogen sulphide were compared to the levels established under the NS Air Quality Regulations listed in Table 10. The Ontario and Alberta provincial standards are also listed for information purposes only.

Table 10: Current Ambient Air Quality Objectives for Hydrogen Sulphide (H_2S)

Standard/Objective	24 hour (ppb)	1 hour (ppb)
Nova Scotia Air Quality Regulations	6	30
Ontario Ambient Air Quality Standards	5	--
Alberta Ambient Air Quality Standards	3	10

The maximum concentrations and maximum daily averages for H_2S in each year are shown in Table 11, along with annual averages. The maximum values fall well below the NS permissible standards, although there were some daily averages that approached or exceeded the Alberta 24-hour standard.

Table 11: H_2S Hourly and Daily Maxima and Annual Average Results for 2003 to 2006

Year	Maximum Concentration (ppb)	Maximum Daily Average (ppb)	Annual Average (ppb)
2003*	2	2	0.13
2004	3	2.5	0.76
2005	6	3.9	1.19
2006**	4	2.9	0.96

* 2003 – approximately one month of measurements
**2006 – January 1 to May 31

The frequency distributions for both the daily averages and daily maxima show the majority of measurements are below 2 ppb, as illustrated in Figures 15 and 16 respectively. This is well below the NS permissible levels. The data from 2003 are not shown because only one month of data was available, making distribution comparisons impractical. There is a shift between 2004 and 2005, with higher counts in the upper levels in 2005, showing a possible shift to elevated levels of H_2S over time. This cannot be confirmed with the 2006 data at the present time.

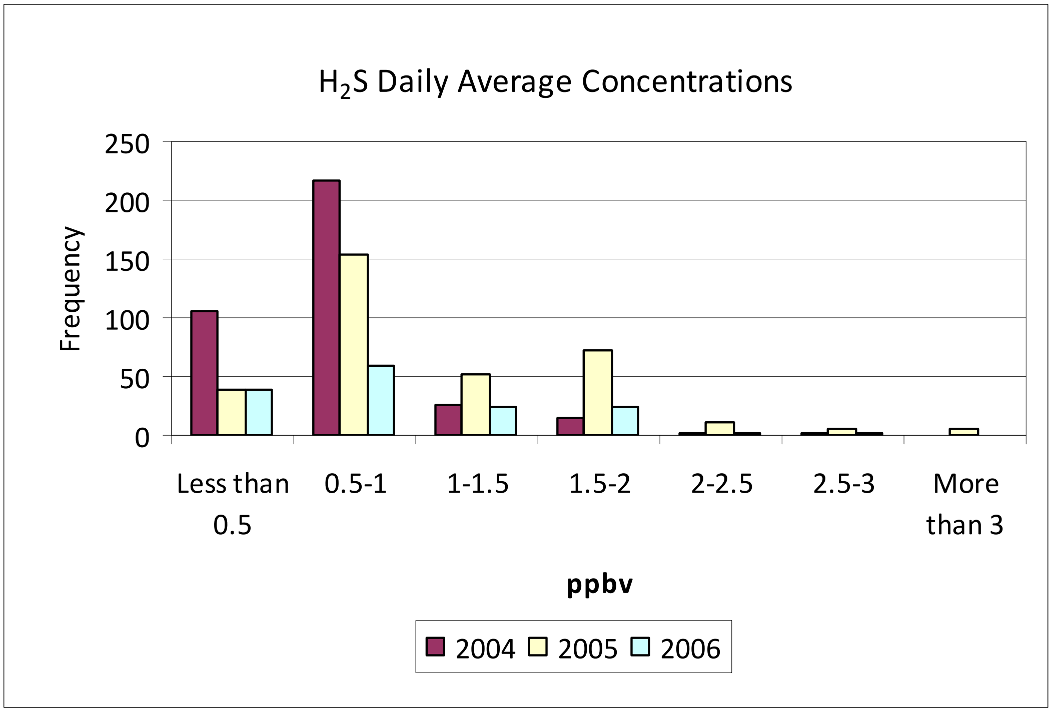


Figure 15: Frequency Distributions for Sable Island Hydrogen Sulphide (H_2S) Daily Average Concentration for 2004, 2005 and January Through May 2006 (2003 not shown because only 1.5 months of data were available)

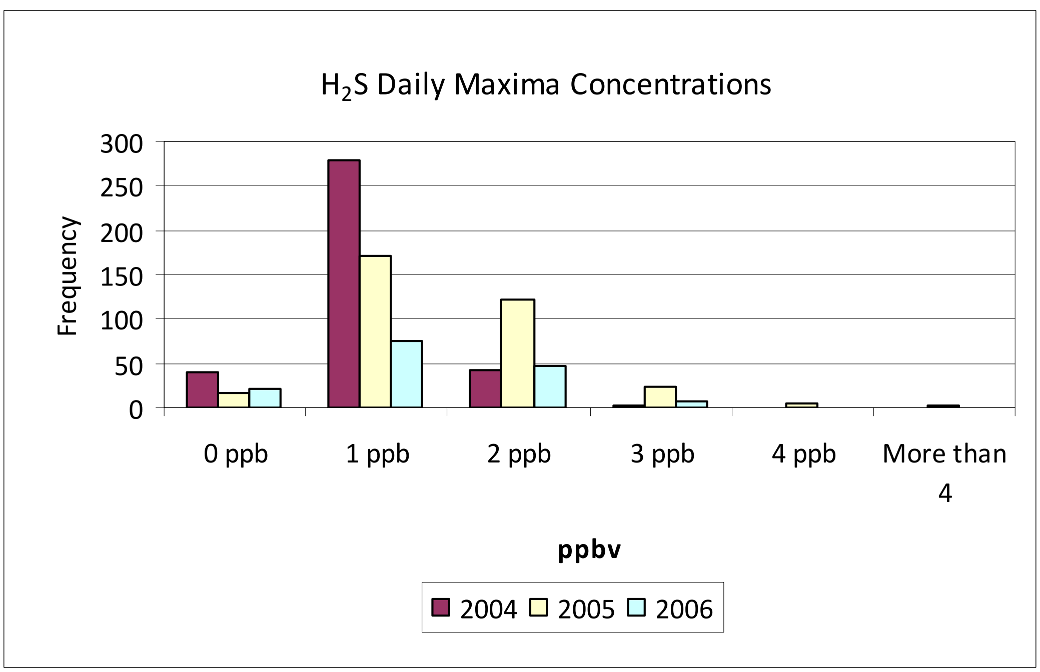


Figure 16: Frequency Distributions for Sable Island Hydrogen Sulphide (H_2S) Daily Maxima Concentration for 2004, 2005 and January Through May 2006 (2003 not shown because only 1.5 months of data were available)

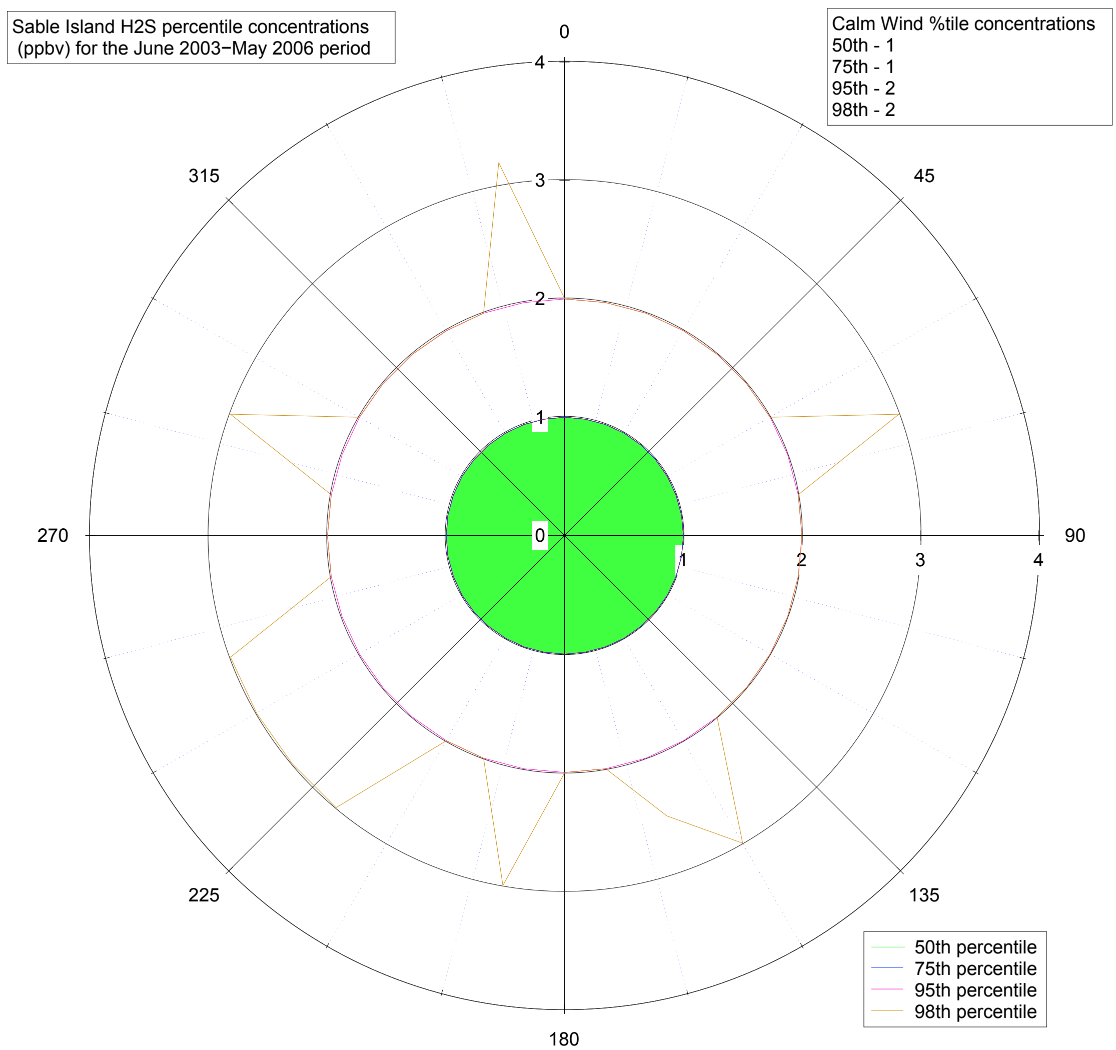


Figure 17: Plot of the Sable Island H_2S Percentile Concentrations (in ppbv) by Wind Direction for the June 2003–May 2006 Period
(Note that the 50th and 75th percentile ranges are coincident). There does not appear to be any significant wind directional influence on the H_2S concentrations from this analysis.

Figure 17 provides an analysis of wind direction and H_2S concentrations recorded on Sable Island over the years from 2003 to 2006. The results do not show any significant influence of wind direction on the H_2S concentrations recorded at the station. As a result, it is not possible at the present time to associate the H_2S concentrations with a particular source.

4.1.5 SO_2 Results

As with H_2S data, SO_2 results are reported every second hour and were subject to the same issues of instrument drift in the latter part of 2006. Again, only a portion of that year's data was used in the following analysis.

There are currently no Canada Wide Standards for ambient levels of SO_2. The concentrations of SO_2 on Sable Island were compared to the National Ambient Air Quality Objectives (NAAQO) for sulphur dioxide. Nova Scotia's Air Quality Regulations set permissible levels of SO_2 equivalent to the acceptable levels of the NAAQO. Concentrations were also compared to the World Health Organization's Ambient Air Quality Guidelines for sulphur dioxide. A list of these objectives is shown in Table 12.

Table 12: Current Ambient Air Quality Objectives for Sulphur Dioxide (SO_2)

Standard/Objective	1-Hour (ppb)	24-Hour (ppb)	Annual Average (ppb)
National Ambient Air Quality Objectives	172 (desirable) 334 (acceptable)	57 (desirable) 115 (acceptable)	11 (desirable) 23 (acceptable)
Nova Scotia Air Quality Regulations	--	112	22
World Health Organization Ambient Air Quality Guidelines	--	7.5	--

There were no exceedances of any of these objectives over the measurement period and in fact the 1-hour and 24-hour concentrations were well below these levels. The annual averages also fall well below the levels established by either the NAAQO or Nova Scotia. The maximum daily and hourly measurements and the annual averages for SO_2 measurements are provided in Table 13.

Table 13: SO_2 Hourly and Daily Maxima and Annual Average Results for 2003 to 2006

Year	Maximum Hourly (ppb)	Maximum Daily Average (ppb)	Annual Average (ppb)
2003*	1.8	1.0	0.6
2004	2.8	2.6	0.8
2005	5.3	4.2	1.3
2006**	3.4	2.8	1.1

* 2003: approximately one month of measurements
**2006: January 1−May 31

The frequency distributions for the daily average concentrations and daily maximum concentrations are shown in Figure 18 and 19, respectively. The data from 2003 are not shown because only one month of data was available, making distribution comparisons impractical. It should be reiterated that the SO_2 measurements are recorded bi-hourly because the instrument switches between measuring H_2S and SO_2.

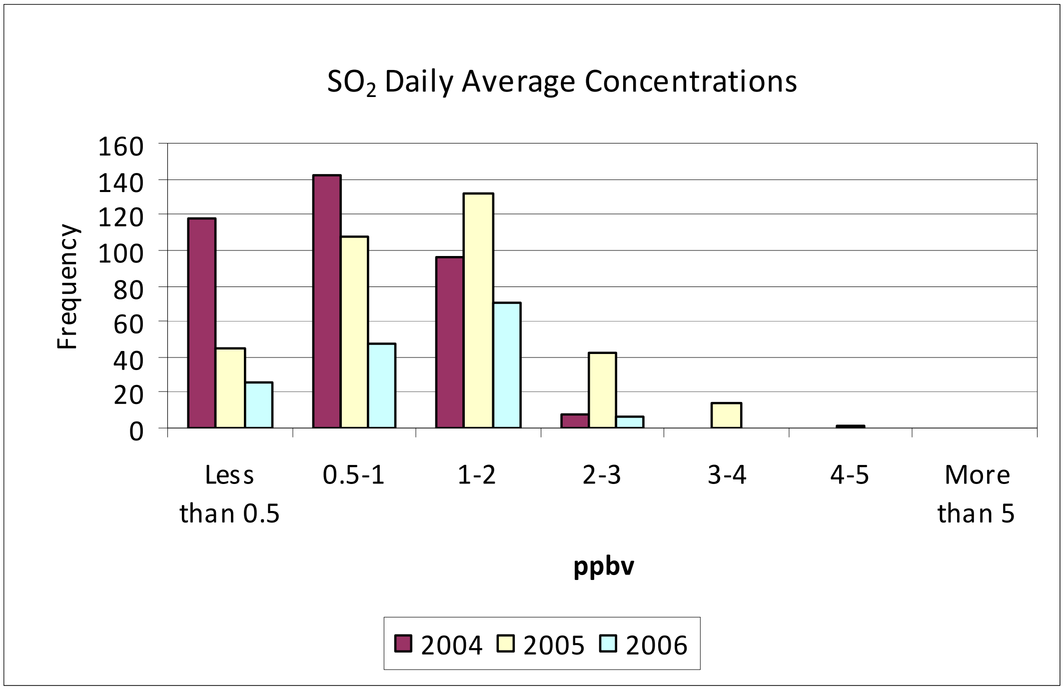


Figure 18: Frequency Distributions for Sable Island SO_2 Daily Average Concentrations for 2004, 2005 and January Through May 2006 (2003 not shown because only one month of data was available)

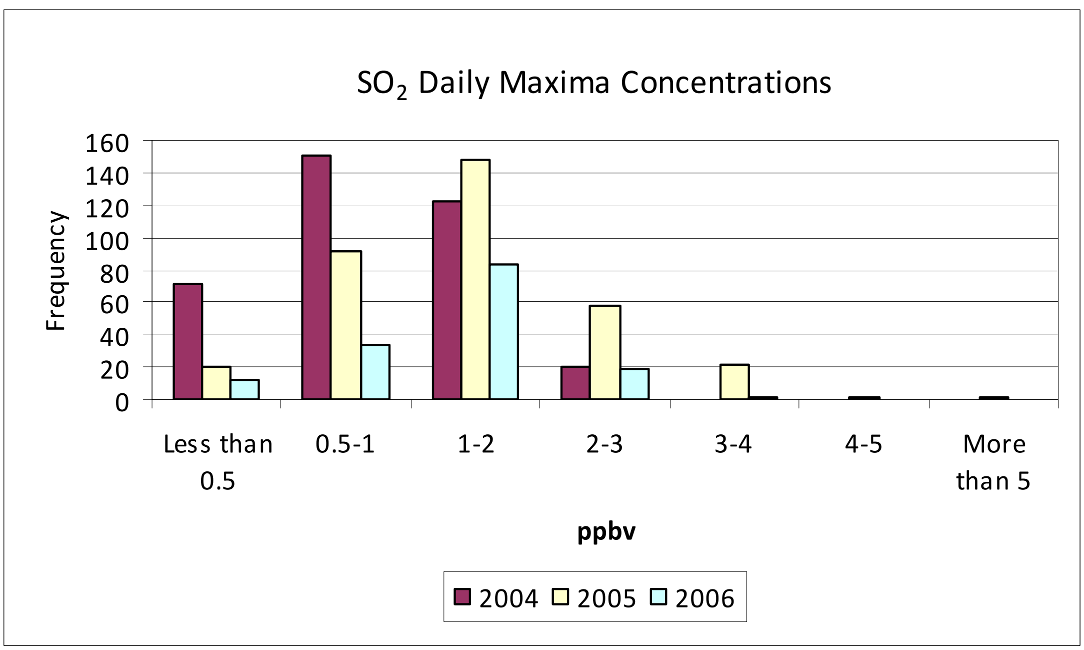


Figure 19: Frequency Distributions for Sable Island SO_2 Daily Maxima Concentrations for 2004, 2005 and January Through May 2006 (2003 not shown because only one month of data was available)

There is a distinct increase among the distributions for both the daily averages and the hourly maxima. The annual average measurement of SO_2 increased from 2003 to 2005 and remained higher for 2006. That said, the concentration levels are still low when compared to any of the established air quality objectives for sulphur dioxide.

Figure 20 provides an analysis of wind direction and SO_2 concentrations recorded on Sable Island over the years from 2003 to 2006. As with H_2S, the results do not show any significant influence of wind direction on the SO_2 concentrations recorded at the station and it is not possible to associate the SO_2 concentrations with a particular source.

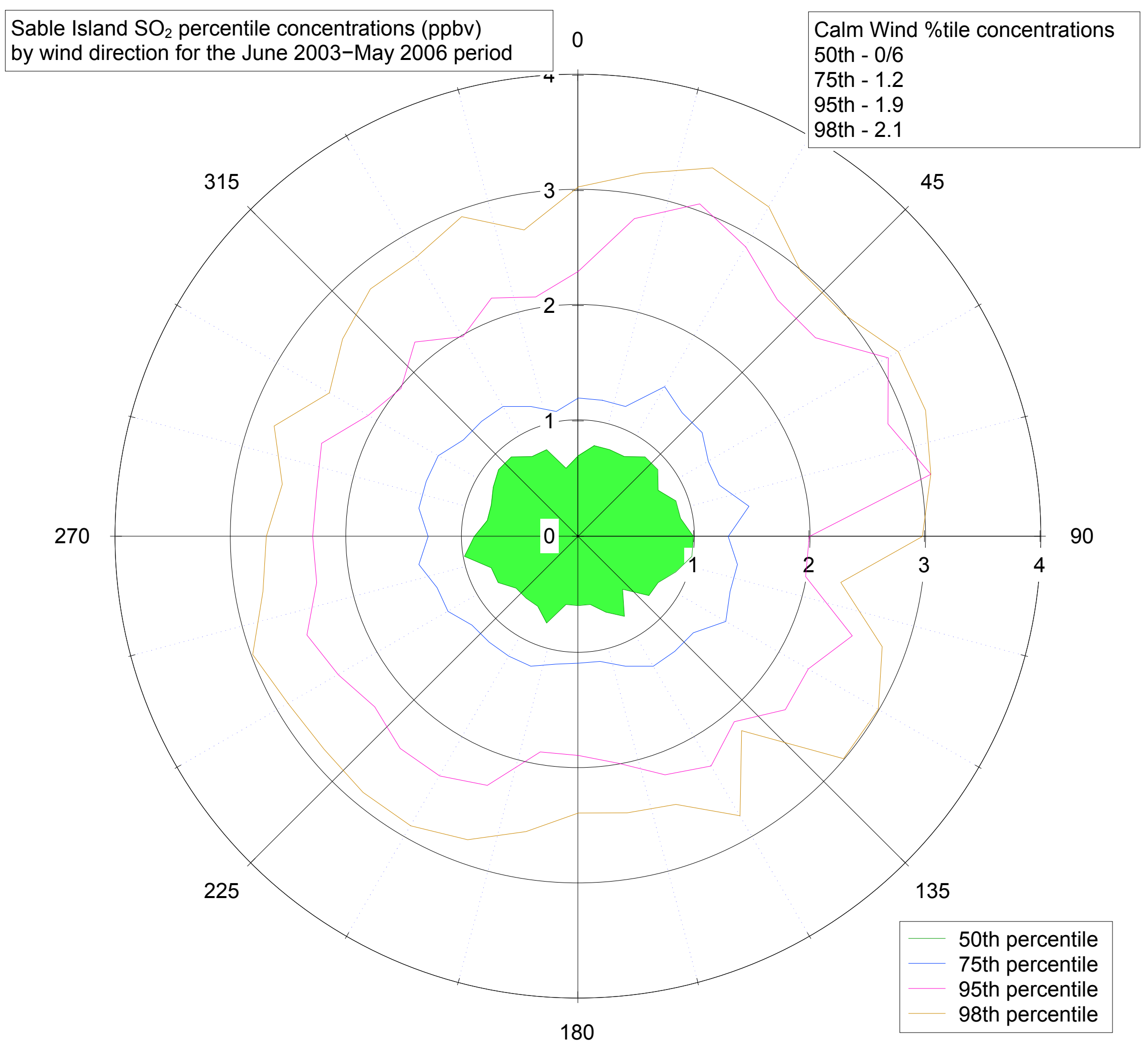


Figure 20: Plot of the Sable Island SO_2 Percentile Concentrations (in ppbv) by Wind Direction for the June 2003–May 2006 Period

There does not appear to be any significant wind directional influence on the SO_2 concentrations from this analysis.

4.2 *Elevated Pollution Events*

Based on the monitoring data, various episodes containing elevated pollutant values were identified and are listed in Tables 14 to 17, along with possible causes for the event. Several of these episodes (highlighted in the following tables) were selected for further analysis in order to determine an underlying cause for the high values recorded (i.e., transboundary flows, local effects or natural influences). These events were analysed using back-trajectories and regional monitoring records and the results are discussed in more detail in Section 5.

Table 14: Elevated Pollutant Events in 2003

Date	Pollutant(s)	Possible Causes
June 7-9	Ozone	Long-range transport
June 29-30	Fine particulate ($PM_{2.5}$)	Long-range transport
July 6-7	Fine particulate ($PM_{2.5}$)	Long-range transport
July 27-28	Fine particulate ($PM_{2.5}$)	Long-range transport
August 27-28	Fine particulate ($PM_{2.5}$)	Possible long-range transport[14]

Table 15: Elevated Pollutant Events in 2004

Date	Pollutant(s)	Possible Causes
February 19	Fine particulate ($PM_{2.5}$)	Sea-salt aerosol loading (winter storm)
June 9-10	Fine particulate ($PM_{2.5}$)	Long-range transport
July 31	Ozone	Long-range transport
November 5-7	Hydrogen Sulphide	Possible local or natural influences
December 2	Nitrogen Oxides	Emission sources on Thebaud platform
December 12-16	Sulphur Dioxide	Possible local or natural influences

Table 16: Elevated Pollutant Events in 2005

Date	Pollutant(s)	Possible Causes
January 24	Fine particulate ($PM_{2.5}$)	Sea-salt aerosol loading (winter storm)
March 9	Fine particulate ($PM_{2.5}$)	Sea-salt aerosol loading (winter storm)
April 20-21	Fine particulate ($PM_{2.5}$) Ozone Hydrogen Sulphide	Long-range transport with possible local or natural influences
May 29	Nitrogen Oxides	Diesel generator on Sable Island and/or Venture platform
June 26	Fine particulate ($PM_{2.5}$)	Long-range transport
October 13	Nitrogen Oxides	Diesel generator on Sable Island and/or Venture platform
October 25-26	Hydrogen Sulphide Sulphur Dioxide	Possible local or natural influences

[14] A lack of available data makes it difficult to determine the exact cause of this event.

Table 17: Elevated Pollutant Events in 2006

Date	Pollutant(s)	Possible Causes
February 23	Nitrogen Oxides	Diesel generator on Sable Island and /or Venture platform
March 27	Fine particulate ($PM_{2.5}$)	Sea-salt aerosol loading (winter storm)
June 21-22	Ozone	Long-range transport
July 2-3	Fine particulate ($PM_{2.5}$) Ozone	Long-range transport with local contributions from Thebaud platform
September 13	Fine particulate ($PM_{2.5}$)	Sea-salt aerosol loading (Tropical Storm Florence)

5.0 DISCUSSION

High pollutant values recorded at the Sable Island monitors can result from a number of factors, including long-range transport of pollutants, emissions from local sources (e.g., offshore oil and gas activities, diesel generation and waste incineration at the research station) or natural sources (lightning, stratospheric ozone intrusions and sea-salt spray).

In order to draw conclusions regarding the underlying cause of a high pollutant event, it is necessary to carry out an analysis of the event and examine relevant back-trajectories and the values recorded at other air monitoring stations in the region. Air quality modeling scenarios may also be used in some cases. Information on local emission sources (e.g., flaring observations) can also be used to help determine the source of the elevated events.

The selected events listed in Section 4.2 were examined in detail and conclusions were drawn (where possible) regarding the primary sources influencing the events. Back-trajectories for each of the transboundary-influenced events are provided in Appendix E. A map showing the location of land-based monitoring stations in Nova Scotia is provided in Appendix F. Smoke observation data for the Thebaud platform were also provided for the analysis.

5.1 Transboundary Flows

June 7-9, 2003 – Long-Range Transport Ozone Event

Long-range transport of pollution was evident in this event because back-trajectory analysis showed that air parcels crossing Kejimkujik late on June 7 resulted in ozone peak concentrations of 75 ppb (2000-2100 LST). This was followed by peak ozone concentrations at Sable Island of 74 ppb on June 8. The Dayton (Yarmouth) observations also indicated elevated ozone concentrations in the early evening of the 7th. This is an excellent example of a long-range transport event and the closeness of the maximum readings is as close as any examples found in recent episode studies.

June 29-30, 2003 – Wide-Scale Regional/Transboundary $PM_{2.5}$ Event

The $PM_{2.5}$ concentrations increased early on June 29 and reached a maximum of 61 $\mu g/m^3$ by late evening then remained close to 30 µg/m3 in the overnight period, climbed to 43 $\mu g/m^3$ in the late afternoon and then decreased after that point. Concentrations at some of the other Nova Scotia mainland sites were above 30 $\mu g/m^3$ for a few days prior to the 29th, beginning as early as June 25 in Moncton and reaching a maximum of 56 ug/m^3 at Pictou on June 27 and 48 ug/m^3 at Kejimkujik on June 28. Back-trajectories were from the southwest through the northwest having originated over southern Ontario, southern Quebec and New England. AIRNow maps were not available until October 2003.

June 9-10, 2004 Long-Range Transport $PM_{2.5}$ Event

This event affected most of the $PM_{2.5}$ monitoring sites in Nova Scotia and southern New Brunswick and has been presented at various scientific fora.

Figure 21 illustrates the progression of the $PM_{2.5}$ concentrations across various Nova Scotia sites during the widespread $PM_{2.5}$ event of June 9-10, 2004. The Sable Island concentrations were similar to values reported at Pictou and Sydney and were higher than Kejimkujik. A peak concentration of 56µg/m^3 on Sable Island relates to peak concentrations at Sydney of 55µg/m^3. Back-trajectories indicate sources for the event originating over southern Ontario and the US eastern seaboard.

The rapid increase in $PM_{2.5}$ concentrations followed later by a rapid decline immediately following the cold front passage is indicative of sharply defined pollutant plumes. Ozone concentrations were also elevated during this event.

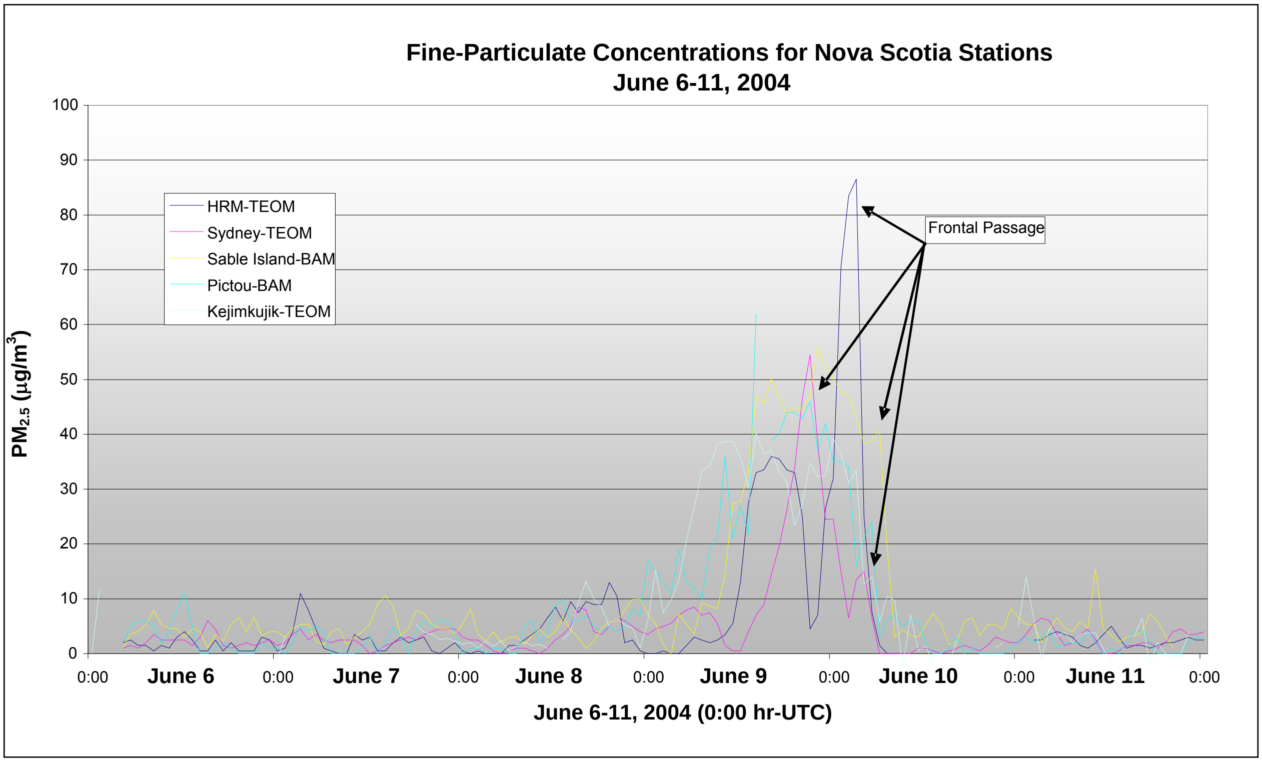


Figure 21: Time Series of $PM_{2.5}$ Concentrations at Nova Scotia Stations (Including Sable Island), June 6-11, 2004
(*Credit: McPherson and Waugh: Poster Submitted to the Atmospheric Deposition Network Technical Workshop, Sept. 2004, and CMOS Congress Presentation # 3C4.3, June, 2005*)

5.2 Local and Natural Influences

It is difficult, if not impossible, based on the information currently available, to draw firm conclusions regarding the influence of local sources on specific high pollutant events. However, the presence of some isolated extreme values in the data set lasting only an hour or two does raise the possibility of local source influences, as opposed to transboundary pollutant flows. These local sources may result from offshore oil and gas activities in the vicinity of Sable Island (see Figure 1), from passing marine traffic,[15] or from power generation or other activities occurring on Sable Island (see Figure 2).

[15] Recent particle count measurements on Sable Island show transient effects from passing ships lasting only a maximum of 30 minutes.

In addition to causing specific pollutant episodes or extreme values, local sources may contribute to a general increase in the pollutant levels recorded. Hence, even if the overall cause of a high pollution episode is related to transboundary flow, local emissions may contribute additional pollutants to the air parcel, thereby raising the values recorded by the monitors and influencing overall air quality in the region.

There is some evidence of local source influences in the NOx data. These infrequent NOx spikes occur mainly during the overnight period with light winds from the east to northeast and appear to be associated with sources at the Sable Island station, including the diesel electricity generator, emissions from forced air furnaces, vehicles, etc.[16] Given the direction, it is also possible these NOx spikes may result from emissions of the diesel generator on the Venture offshore platform. There is also some evidence of NOx levels recorded from the direction of the Thebaud offshore platform (diesel generator or flare).

Smoke observation data from the Thebaud offshore platform were provided for periods in 2003, 2004 and 2005 and all of 2006 and provide some indication of the potential influence from this source on $PM_{2.5}$ concentrations when used in combination with the wind direction and air quality data recorded. In the fall of 2006, personnel on the Thebaud platform began to perform twice-daily flare observations using a smoke chart. This more standardized reporting format should assist in data analysis in the future.

As with local sources, it is not currently possible to reach solid conclusions regarding the influence of natural sources on Sable Island air quality. Additional monitoring, including PM speciation to determine sea-salt concentration, meteorological observations regarding lightning events and further research into stratospheric ozone intrusions and sulphur-reducing bacteria could help to determine what impact, if any, these types of factors are having on the data collected at Sable Island. Ongoing and future air quality modeling work may also help in this regard. In any case, when analysing and interpreting the monitoring results, it is important to keep in mind the possibility that natural influences may be affecting air quality on Sable Island.

Further analysis of the impact of local and natural sources will require the co-operation and input of project partners in order to correlate any specific activities or sources that may influence air quality with the values being recorded at the Sable Island station.

Specific pollutant events that may show local or natural influences are discussed below.

February 19, 2004 – Potential Case for Sea-Salt Aerosol Contribution to $PM_{2.5}$

Concentrations of $PM_{2.5}$ increased on Feb 19, 2004 to reach 25 $\mu g/m^3$ by late afternoon as a strong low pressure area approached Sable Island (Figure 22). Concentrations exceeded 30 $\mu g/m^3$ from 6 pm to 11 pm with a peak concentration of 50 $\mu g/m^3$ at 9 pm. Precipitation ended by noon and gale to storm force easterly winds diminished to moderate south-easterly winds at the time when $PM_{2.5}$ began to increase. Winds diminished further and became light (<10 km/h) at the time of highest concentrations as the low was passing over the site and surface pressure began to rise. Winds increased to strong north-westerly and $PM_{2.5}$ concentrations decreased to 6 $\mu g/m^3$ by midnight of the 19th. See Appendix G for a graph comparing $PM_{2.5}$ concentrations during this event with the associated wind and wave data.

[16] The building site for the Sable Island monitor was chosen to minimize the "contaminated sector" caused by the station and comprises the sector from about 040 to 090 True North.

Back-trajectory analysis does not indicate that air parcels passed over emission source areas in the near term—and where it may have transited across Sydney or Port Hawkesbury, NS, the air parcels would have passed through an area of precipitation that would have “washed out” the bulk of the $PM_{2.5}$. Corresponding NOx data do not indicate that there was an influence from the local generator during this period and attribution to other potential sources in the vicinity of Sable Island seems unlikely during this period of light winds.

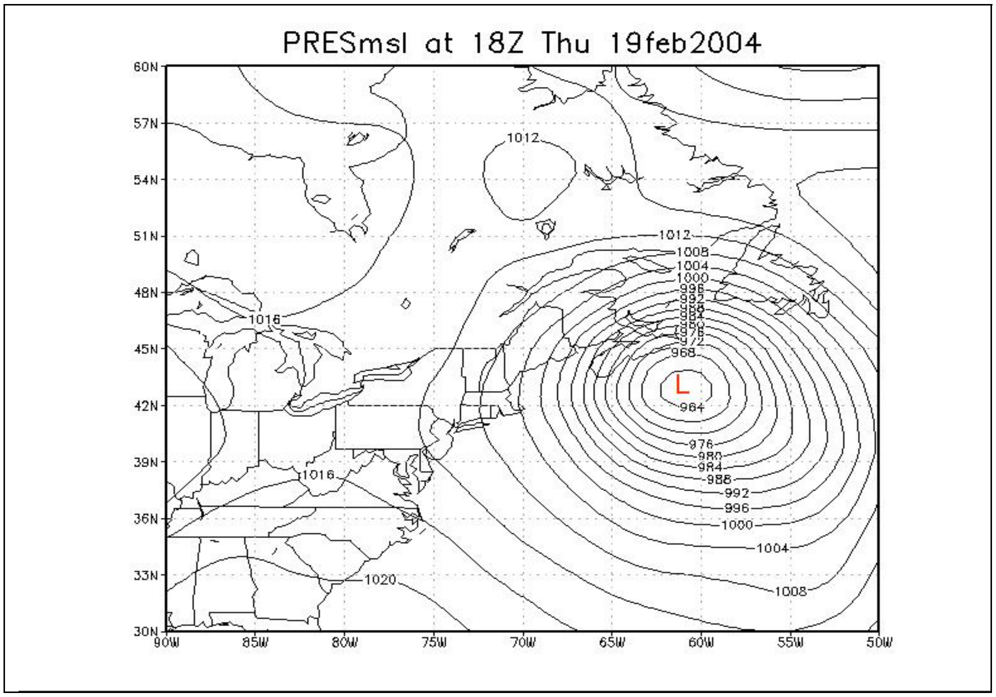


Figure 22: Mean Sea Level Pressure Analysis for 1800 UTC, Feb. 19, 2004

The most plausible explanation is that the maximum $PM_{2.5}$ concentrations occurred during a period of light winds because the high energy waves lagged the storm force winds. This resulted in heavy sea salt aerosol loading from breaking waves on the beaches and in the shallow water depths around Sable Island during the time when the winds were light (<10 km/h). Investigations into these sea salt aerosol loading cases are limited by the lack of speciated PM data from Sable Island, which was not established until November of 2006. Phinney[17] reports on investigations of sea salt aerosol and Farrell[18] has conducted a chemical transport model scenario to investigate the physical mechanisms that contribute to sea salt aerosol loading in the lowest levels of the atmosphere.

[17] Phinney, L., 2008. Sea Salt Aerosol Surface Concentrations and Vertical Profiles near the Atlantic Canadian Coast: a Literature Review. Meteorological Service of Canada – Atlantic Region Science Series 2007 - 0X.

[18] Farrell, T.C., 2006. The Contribution of Naturally Occurring Sea Salt to Fine Particulate Matter Concentrations in the Atlantic Region. Presented to the 40th Congress of the Canadian Meteorological and Oceanographic Society, Toronto, Ontario, June 1, 2006, Meteorological Service of Canada.

December 2, 2004 – Possible Local Source Influence on NOx Concentrations

NOx concentrations reached a maximum of 16 ppb at 0800 AST with winds from 250−260 degrees at approximately 40 km/h just prior to the observation. The wind direction suggests that the source for the elevated concentrations may be the emission sources on the Thebaud platform (i.e., the diesel generator or flare). Note the slight association with elevated NOx concentrations and the 250-degree wind direction in Figure 14. As discussed in section 4.1.3, however, NOx concentrations in the Sable Island area are well below allowable provincial, national and international standards.

April 20-21, 2005 − Long-Range Transport with Possible Local or Natural Influences

Ozone and $PM_{2.5}$ concentrations were elevated prior to this period over the northeastern US and southern Canada and back-trajectory analysis indicates that the air parcels arriving at Sable Island crossed these emission-rich areas 2 to 3 days prior. $PM_{2.5}$ concentrations at Sable Island peaked at 37 $\mu g/m^3$ at 1500 AST on April 20 and ozone peaked at 60 ppb at 1300 AST on the same day. Surface winds during the afternoon of the 20th were from the west to west southwest, and wind speeds were generally in the range of 25−35 km/h at most; so there should not have been an influence from sea salt. By early on the 21st of April, the winds were from the southeast generally.

H_2S concentrations were also elevated from April 17 to 21, with maximums reaching 4 ppb and the highest daily average for the year on April 18 at 3.9 ppb. Owing to the "sweet" nature of the gas produced by the Sable Offshore Energy Project, significant H_2S emissions from this source appear unlikely.[19] H_2S emissions can result from respiration of sulphur-reducing bacteria in anaerobic soils; however, the lack of any tidal flats on Sable Island makes this source unlikely as well.[20] Since there is currently no other information available on potential local or natural sources of H_2S emissions, the source of the elevated concentrations during this episode remains unattributed at present. Note that these concentrations are still below NS permissible levels.

May 29, 2005 and February 23, 2006 − Possible Local Source Influence on NOx Concentrations

During the May 29 event, NOx concentrations reached a maximum of 12 ppb at 2300 AST. Winds were from the 070−090 direction at nearly 10 km/h for a couple of hours leading up to the maximum with a surface temperature of 6^{o}C and drizzle reported prior to the reading.

During the February 23 event, NOx concentrations reached a maximum of 47 ppb at 0400 AST with light winds calm during the period and surface temperature at -6^{o}C or lower prior to the reading. Winds a few hours prior were from the 070-degree direction at 11 km/h. Concentrations climbed around midnight when winds were calm.

The wind direction suggests that the source of the elevated concentrations in both cases is either the diesel generator on Sable Island and/or the generator on the Venture platform. Note the strong association with elevated NOx concentrations and the 070−090-degree wind direction in Figure

[19] Initial testing of SOEI natural gas in the 1990s showed trace amounts of H_2S in the range of 6-8 ppm (Elizabeth Macdonald, CNSOPB, pers. com, November 12, 2008).
[20] Email from Zoe Lucas, September 23, 2008

14. As previously mentioned, however, NOx concentrations in the Sable Island area are well below allowable provincial, national and international standards.

July 2-3, 2006 − Long-Range Transport with Possible Local Source Influence on $PM_{2.5}$

The case of July 2-3, 2006 is believed to be a combination of long-range transport and local contributions.

Concentrations on July 3 climbed to 40 µg/m^3 in the afternoon and peaked at 219 µg/m^3 by 1700 AST when surface winds were from the direction of the Thebaud platform (250 degrees). Back-trajectory analysis indicates that the origin of the air parcels arriving on Sable Island during the afternoon of July 3 was the northeastern US. As shown in Figure 23, $PM_{2.5}$ concentrations recorded in these US areas on July 2 ranged from 30 µg/m^3 to 45 µg/m^3 with a few sites recording hourly concentrations from 55 µg/m^3 to 60 µg/m^3. These concentrations are still well below the 219-µg/m^3 concentration measured at Sable Island on July 3.

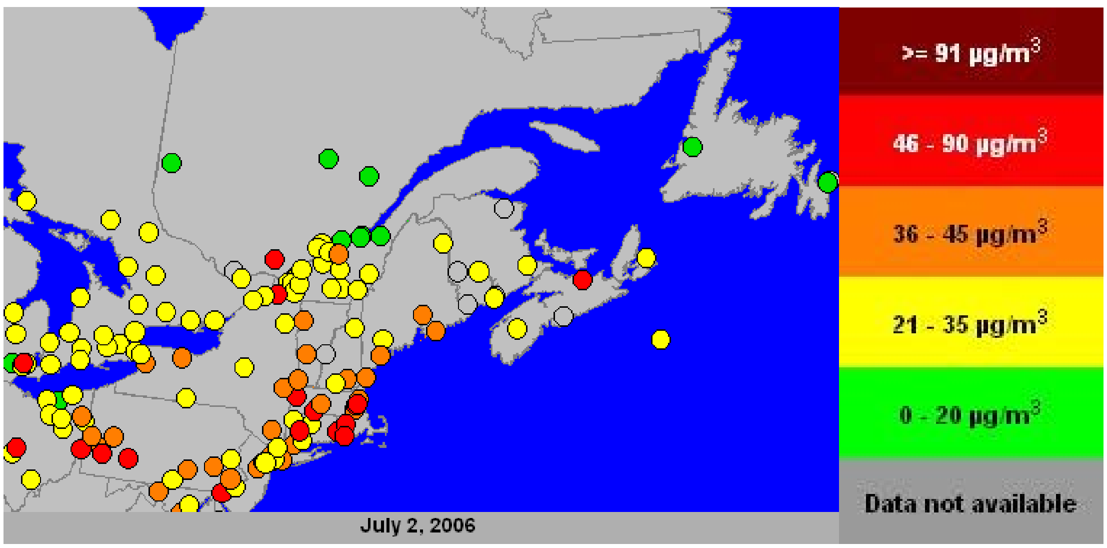


Figure 23: AirNow Chart Showing $PM^{2.5}$ Concentrations Recorded at Monitors Across the Northeastern United States and Eastern Canada on July 2, 2006

The combined evidence of dark smoke in the flare observation data from the Thebaud platform on July 2 and again on July 4 (fog obscured the flare on July 3) indicates that contributions to Sable $PM_{2.5}$ were likely the result of a combination of long-range transport and rig emissions (highlighted by the peak concentration greater than 200 µg/m^3).

Sept 13, 2006 – Potential Case for Sea-Salt Aerosol Contribution to $PM_{2.5}$

Post-tropical storm Florence formed in the central Atlantic on September 3, 2006 and subsequently moved northwest towards Bermuda and reached maximum strength as a hurricane on September 10 with maximum sustained winds of 140 km/h. Subsequently it moved northeastward and was downgraded to an extra-tropical storm on September 12 as it moved north of the Gulf Stream waters (Fogarty, 2008). The storm passed approximately 150 nautical miles east of Sable Island early on September 13 (Figure 24) and continued moving northeastward towards the Avalon Peninsula as a deepening storm on that day. Surface winds on Sable Island increased to 65 km/h from the north near midnight on the 12th with reported gusts to 90 km/h when the $PM_{2.5}$ concentrations on Sable reached their maximum of 125 μg/m^3. Significant wave heights reported from the Triumph platform (35 km south-southeast of the Sable Island monitoring site) were sustained at 4+ m for more than 12 hours and reached 5.6 m. Maximum wave heights were 12.5 m. Thebaud significant waves were 4+ m for 5 hours with the maximum wave height at 16.5 m near midnight on September 12, while Venture had significant waves at 4+ m for 18 hours with maximum waves at 11 to 12 metres for an extended period. The orientation of the sustained winds, the running sea and swell direction, the bathymetry and the degree of sheltering from the seas by the Sable Island land mass are all factors contributing to the variation in the significant wave heights and maximum wave heights at the three platforms. See Appendix G for a graph comparing $PM_{2.5}$ concentrations during this event with the associated wind and wave data, as well as graphs of maximum wave height at all three offshore platforms.

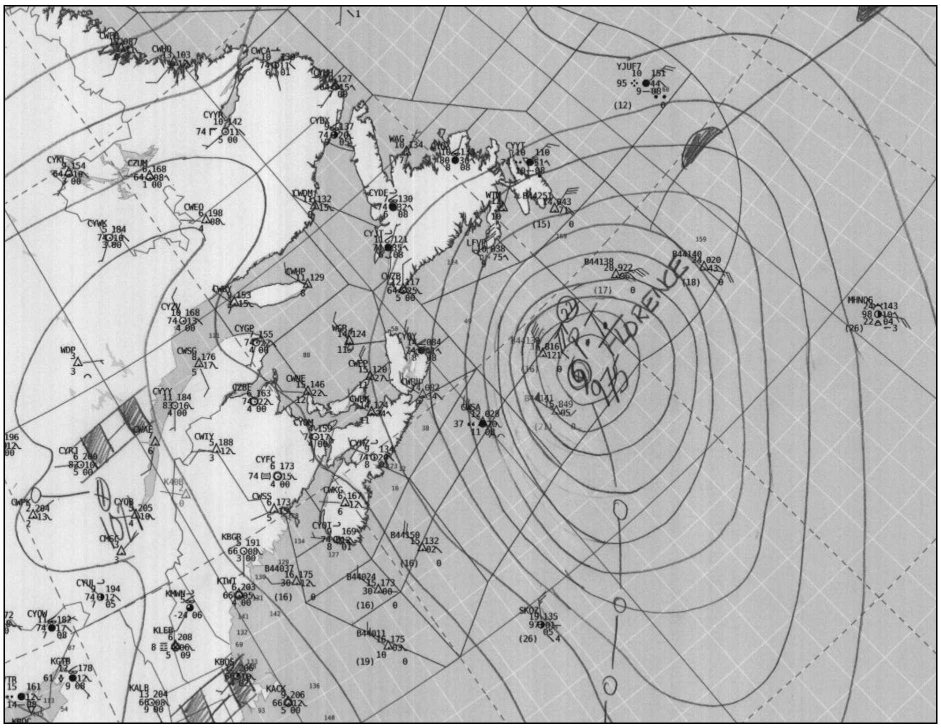


Figure 24: Surface Analysis 0600 UTC Sep 13, 2006 Showing Post-Tropical Storm Florence Located 140 nm East of Sable Island and Moving North-Northeastward at 22 Knots

6.0 CONCLUSIONS AND RECOMMENDATIONS

Overall, the Sable Island Air Monitoring Program has produced some useful results in its first four years of operation. The program has proved valuable in assessing local air quality on the island itself, providing baseline data and in contributing to a greater understanding of air pollution dynamics in the Atlantic Region as a whole. Data from Sable Island are also being used to improve air quality modeling scenarios and to validate air quality models.

Air monitoring data from this project have shown that Sable Island can be affected by the long-range transport of air pollution from the continental mainland. There is also some evidence of natural influences on $PM_{2.5}$ concentrations from sea-salt aerosol loading during storms with high wave action. However, the monitoring program and current observations of various emission-producing activities on and around the island do not yet allow for confirmation as to whether the effects of offshore oil and gas activities can be measured on the island. In particular, based on the current information, the cause of H_2S and SO_2 peaks in the data set is especially hard to attribute to any particular source. Continued operation of the Sable Island Monitoring Station, including improved PM speciation data and better activity observations in the area, will help to clarify which emission sources affect Sable Island.

Any expansion of the program in the future could include additional sensors and components to help separate local and long-range influences (e.g., NOy measurements, VOC filter sampling). As well, research into potential natural emissions sources, especially sulphur compounds, would be useful for assessing the relative impacts of oil and gas activities.

Ongoing efforts will help to improve the quality of the data collected on the island as well as contribute to a greater understanding of how various sources of air pollution impact air quality in the vicinity of Sable Island. The continued support and co-operation of project partners will be vital to ensuring the repeated success of the program into the future.

Specific recommendations to improve the Sable Island Air Monitoring Program are as follows:

- Investigate options to improve the function and maintenance of the monitoring equipment on Sable Island to ensure access to complete and reliable data information for the project;

- Use CO data and NO/NO_2 ratios in future program reports to assist in examining the impact of local emission sources;

- To the extent possible, project partners should provide information on emissions from local sources and activities on or near the island in order to improve understanding of the influence of these emission sources on Sable Island air quality (e.g., flare observation data for offshore oil and gas platforms; waste incineration on Sable Island); and

- Given its early success and the satisfaction expressed by project partners, consideration should be given to extending the Sable Island Air Monitoring Program into the future.

7.0 NEXT STEPS AND FUTURE PLANS

The next steps for the Sable Island Air Monitoring Program include the following:

- Funding for the program ended in the 2006−2007 fiscal year. Discussions are being held on the feasibility of continuing the program under the current process or an alternative arrangement.

- Some investigation should be done regarding the possibility of a long-term stable funding source for the Sable Island program.

- In November 2006, a PM speciation monitor was set up on Sable Island. Future analysis of this information should help to determine the cause of air quality events in the Sable Island area.

- There are plans to set up an additional Teledyne monitor at the Sable Island station in 2009. This will allow SO_2 and H_2S measurements to be recorded separately and will eliminate the hourly switching that occurred in the past. More frequent measurements, as well as the ability to report this information to NAPS, should allow for a much better analysis of these pollutants and their potential sources.

- New data management procedures were implemented in October 2008. There are plans to make the Sable Island monitoring data available in real time to the public, as is done by other air monitoring stations in Nova Scotia.

- Program partners have agreed to discuss a co-operative arrangement to notify one another of events or activities related to the program. Efforts will be made to alert industry as soon as possible in the event that high pollutant values that may be attributable to oil and gas activity are recorded. In turn, industry will attempt to notify other partners of any planned activities or events that may have an impact on levels recorded at the Sable Island station.

- Results from monitoring data in 2007 and 2008 will be provided in a follow-up report sometime in the future.

Appendix A − Airshed Monitoring for Petroleum-Related Activities in the Scotian Shelf Area

Technical Proposal for Funding from the Environmental Studies Research Fund (ESRF) Levies Made Under Part VII of the Canada Petroleum Resources Act

1.0 INTRODUCTION

Background

In September 1999, the CNSOPB received notification from personnel on Sable Island of their exposure(s) to an unconfined vapour/aerosol plume originating from a flare at a Sable Offshore Energy Installation (SOEI). The Board investigated the report with SOEI personnel and a retrospective analysis of the event was constructed using estimates of emission rates and computer simulations based on meteorological data collected during the time of flaring. Ambient air monitoring was commissioned by SOEI for selected locations downwind from the installation and additional reports were generated to characterize ambient air quality in the Nova Scotia Offshore Area.

In April 2000, the CNSOPB called a meeting with representatives from Environment Canada, Nova Scotia Environment, Fisheries and Oceans Canada, Sable Island Preservation Trust, Petroleum Research Institute, Canadian Association of Petroleum Producers and other industry stakeholders in order to table the issue of ambient air monitoring in the Nova Scotia Offshore Area. The outcome of this meeting was a consensus that the general issue of ambient air emissions was important and that a multi-stakeholder approach would ensure that a maximum effort was brought to bear on the issue. However, a more specific proposal would nevertheless need to be developed and tabled for further discussion.

On September 21, the CNSOPB submitted an overview of air quality issues and possible monitoring activities to the working group charged with updating the Offshore Waste Treatment Guidelines. As a result of continued interest and feedback from this and other forums, Environment Canada and the Canada-Nova Scotia Offshore Petroleum Board have drafted the following proposal for submission to the Environmental Studies Research Fund.

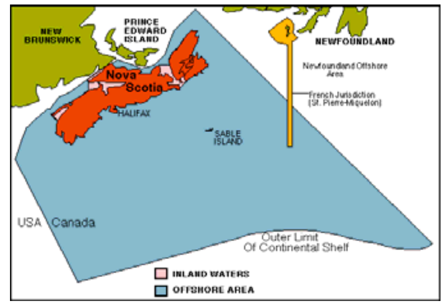
Purpose and Scope of Proposal

The focus of this proposal is to acquire the necessary support for the installation and maintenance of ambient air monitoring equipment at the existing station located on Sable Island so that more representative indications of petroleum-related activity may be obtained. Although improved real-time monitoring from Sable Island is critical, continued support from private and public stakeholders will be required to develop a comprehensive air quality management system. For example, various technical and regulatory sessions will be required to develop consistent protocols for site-specific monitoring and reporting, determine applications for computer-generated imaging and co-ordinate sampling activity at downwind locations other than Sable Island.

As a complete package, the comprehensive air quality management system will provide regulators, industry, and researchers with the necessary data required to evaluate the impacts attributable to contaminant emissions into the ambient air from petroleum-related activities.

AIR QUALITY MANAGEMENT ZONE

Figure 1



Geographical Area

A proposed air quality management zone of this type would be the first of its kind in Atlantic Canada and would include the Nova Scotia Slope and Shelf Offshore Area.
See Figure 1.

Stage 1: Air Monitoring Station

Given the existing infrastructure and technical capability of current resources on Sable Island, it is expected that the ESRF funding would be dedicated primarily to acquiring and installing additional ambient air monitoring equipment. Air emissions primarily associated with upstream oil and gas activity include the following:

- Combustion gas from flares and engine exhaust;
- Particulate matter and other aerosols from incomplete combustion and/or physical-chemical reactions;
- Volatile and semi-volatile organic compounds from incomplete combustion and fugitive emissions; and
- Hydrogen sulphide from “sour” well developments.

Based on this, it is recommended that the ambient air monitoring station on Sable Island should be equipped with the following real-time analysers:

1. NO / NO_2 / NO_X
2. SO_2 (with oxidizer for TRS and H2S)
3. Total hydrocarbons

Training in equipment operation and maintenance may also be required in addition to nominal funding for routine equipment calibration and preventive maintenance. Hook-up to the station will depend on data logging capability and existing manifold arrangement. Once installed, the equipment would be interfaced with computer communications software that would enable land-based users to acquire data. Report generation could be made initially through existing data management systems or through a 3rd party contract.

2.3 Stage 2: Zone Monitoring

As site-specific data collection and reporting processes mature, the air emission plume footprints of various installations, supply vessel routes and seismic activities would begin to be better characterized. To supplement source emission estimates and plume models, much simpler and smaller-scale air monitoring equipment could be installed as a network throughout the offshore area.

Passive exposure monitors (PEMs) are a very inexpensive and easy tool for collecting time-weighted average measurements of combustion gases and volatile organic compounds at locations downwind from oil and gas activities. PEMs are used in this capacity across Canada and around the world. In the case of the Nova Scotia Offshore Area, PEMs would enable downwind measurements to be taken from drill rigs, platforms and seismic vessels operating in locations upwind from predominant sources of emission.

Interestingly, this type of technology was used to generate measurements after the September 1999 flare gas incident on Sable Island. Unfortunately, there are no passive monitors that have been validated for use in the typical types of climate found in our offshore. Preliminary interest has been expressed by Philip Laboratories in participating in a research project that would include the development, validation and maintenance of passive samplers for offshore applications. This would conceivably include graduate student funding from the Atlantic Petroleum Institute, in-kind contributions from the interested laboratory and technology transfers to the province for its ambient air monitoring programs.

3.0 IMPLEMENTATION

3.1 Stage 1

The implementation of Stage 1 of the proposal, which is the focus of this submission, could be achieved through nominal funding toward the use of existing infrastructure, personnel and technical resources on Sable Island. Funding would be provided to the Sable Island Preservation Trust for the purchase, installation and maintenance of the proposed air monitoring equipment. In-kind support from Environment Canada includes the support and maintenance of the infrastructure on Sable Island, a Crown employee and a real-time meteorology program. In addition, ozone and carbon dioxide are currently being monitored by Environment Canada and data can be available in near real-time. If requested, Environment Canada can provide monitoring equipment for methane and carbon monoxide. The Sable Island Preservation Trust will provide administrative and management support at the site on Sable Island. CNSOPB and other stakeholders would be available as required. As Stage 1 approaches completion, it is expected that key stakeholders would have established solid lines of communication and a formal decision-making process for data management.

The successful implementation of Stage 1 of this proposal will primarily lie with the successful candidate responding to an invitation to tender posted by Environment Canada on the MERX system. Terms of reference for the tender will be drafted by Environment Canada, CNSOPB and the Sable Island Preservation Trust and must include a budget as deemed appropriate by the Environmental Studies Research Fund.

3.2 Stage 2

This type of approach will require stakeholders to share decision-making responsibility for air quality as a formal Board of Directors. The Board of Directors would conceivably include voluntary participants from the CNSOPB, Environment Canada, Nova Scotia Department of the Environment, Nova Scotia Petroleum Directorate, Fisheries and Oceans Canada, Sable Island Preservation Trust, Petroleum Research Institute and Canadian Association of Petroleum Producers and other interested parties in the petroleum industry.

This Board of Directors would acquire resources as a collective for the continued development and operation of the comprehensive air quality management system.

4.0 BUDGET

Table 1 provides an estimate of the funding required to implement Stage 1 of the proposal.

Table 1: Estimated Budget

ITEM	COST PER UNIT	# OF UNITS	TOTAL COST
Oxides of Nitrogen	20,000	1	20,000
Oxides of Sulphur	20,000	1	20,000
Total Petroleum Hydrocarbons	20,000	1	20,000
NOx Calibration System	15,000	1	15,000
Data Analysis /Handling	30	300 (hrs)	9,000
Technical Support	30	500 (hrs)	15,000
		TOTAL ($)	99,000

A similar proposal for Stage 2 may be submitted to the ESRF Management Board for 2002, if required.

5.0 SCIENTIFIC APPLICABILITY

Regions 12, 13 and 14 of the Scotian Shelf and Slope Regions

6.0 SPONSORING MANAGEMENT BOARD MEMBERS

Peter Blackall, Environment Canada
C. Andrew Parker, Canada - Nova Scotia Offshore Petroleum Board

7.0 SCIENTIFIC CONSULTATION

Dr. Ian McLaren, Sable Island Preservation Trust
Vince Gagner, Canada-Nova Scotia Offshore Petroleum Board
David Waugh, Environment Canada
Michael Hingston, Nova Scotia Department of the Environment

Appendix B – MOU Regarding Airshed Monitoring on Sable Island

Memorandum of Understanding Between
Environmental Studies Research Funds Management Board
and Environment Canada−Atlantic Region Regarding
Airshed Monitoring on Sable Island

Background

The Environmental Studies Research Funds (ESRF) is a research program that sponsors environmental and social studies. It is designed to assist government decision making related to oil and gas exploration and development on Canada's frontier lands. The ESRF program receives its legislated mandate under the Canada Petroleum Resources Act (CPRA). The ESRF is overseen by a joint government/industry/public Management Board and administered by a secretariat located in the National Energy Board office in Calgary, Alberta.

Purpose

The purpose of this MOU is to facilitate an ESRF contribution to Environment Canada's Atlantic Region for the acquisition of equipment and the setting up and calibration of this equipment on Sable Island. At the December 2000 meeting of the Waste Treatment Guidelines Group, a general consensus was reached that there is interest in reporting emissions released into the air from offshore oil and gas activity. As part of emissions into the air, the "Contaminants of Concern" will include oxides of nitrogen, volatile organic compounds, methane and oxides of sulphur. The industry is also interested in sampling fine particulate matter. Airshed monitoring on Sable Island will be used to collect samples of the above pollutants. The monitoring will be valuable for the validation of pollutant models, end point impact and pollutant concentration trends and exposures.

Equipment Acquisition

Equipment to be acquired will meet or exceed the standards of the National Air Pollution Surveillance Network (NAPS System) and withstand the rigours of the environment on Sable Island. Data will be reported to the NAPS System—where final quality assurance and quality control will ensure data integrity and where the data will be made available to all interested parties.

Therefore, it is proposed that the following monitoring be initiated as part of the ESRF−Sable Air Monitoring Initiative:

NOx: Continuous monitoring that meets or exceeds NAPS standards
SOx: Continuous monitoring that meets or exceeds NAPS standards
Fine Particulate Matter (PM2.5): Continuous monitoring − MetOne system
Volatile Organic Compounds (VOCs): Using an episodic Grab Sample System
Methane: Continuous monitoring that meets or exceeds NAPS standards

The technical committee will ensure compliance with calibration standards and maintenance schedules and ensure that data are reported to the NAPS system and made available to others. Quality assurance and quality control of the data for NAPS will be monitored.

The equipment will be retained by Environment Canada.

Consequences of Not Having the Information

No baseline data will be available to determine the current concentrations of these pollutants.

Industry and Environment Canada will have no evidence as to whether or not oil and gas exploration and development are having an impact.

If these data are not available, it will be difficult to draw up guidelines or draft regulations for emissions to air as oil and gas development on the Scotian Shelf proceeds.

Deliverables

On the technical committee's recommendation, Environment Canada−Atlantic Region will purchase the above-mentioned equipment (where possible under a NAPS Standing Offer through Environment Canada Headquarters). Environment Canada−Atlantic Region and the technical committee will engage a contractor to set up and calibrate the equipment according to the NAPS protocols.

Annual operation and maintenance costs will be shared between Environment Canada−Atlantic Region and the industry throughout the four-year study.

The information obtained will be used to better inform scientists who could submit and interpret this information objectively in various fora.

Payment

Environmental Studies Research Funds will Environment Canada−Atlantic Region with $100,000 to purchase, set up and calibrate this equipment. The funds will be forwarded at the time of signing. Environment Canada−Atlantic Region will provide receipts/proof of performance for all claimed expenditures. Any funding for which receipts/proof of performance are not received by the ESRF Management Board or funding not required will be returned to the ESRF Management Board.

Financial Records/Audit

Environment Canada−Atlantic Region must keep proper accounts and records of the cost of the work and of all expenditures or commitments made by Environment Canada−Atlantic Region, including invoices, receipts and vouchers, which must at reasonable times be available for audit and inspection by authorized representatives of the Board who may make copies thereof and take excerpts therefrom.

Environment Canada−Atlantic Region must provide facilities for audits and inspections and provide authorized representatives of the Board from time to time with such information as the Board may require with respect to the documents referred to herein.

Environment Canada−Atlantic Region must not dispose of the documents referred to herein without the written consent of the Board, but must preserve and keep them available for audit and inspection for such period of time as may be specified elsewhere in the contract or, in the absence of such specifications, for a period of two years following completion of the work.

Investigators and Collaborators

Scientific Team Members:
Environment Canada: David Waugh, Bill Horne and Christine Garron
CAPP: Geoff Hurley
Sable Island Preservation Trust: Jerry Forbes, Bill Crossman
CNSOPB: Vince Gagner
NSDOEL: Michael Hingston
NOAA: Dr. David Parrish, consulting research scientist

Signatures

SIGNED, this ________ day of __________ 2001.

Bonnie Gray
Chairperson
Environmental Studies Research Funds

Garry Pearson
A/Manager
Atmospheric Science Division
Meteorological Services of Canada
Environment Canada
Atlantic Region

Appendix C – TOA for Ambient Air Monitoring Station on Sable Island

Terms of Agreement (TOA) of Commitments Between Contributing Parties
ESRF- 011 Project, ESRF Ambient Air Monitoring Station on Sable Island

Between
Environment Canada

Environment Canada, Atlantic Region (EC)
and
Environmental Technology Centre (ETC)
and
Air Quality Research Branch (ARQB)

And

Canadian Association of Petroleum Producers
(CAPP)

And

Sable Island Preservation Trust
(The Trust)

And

Canada-Nova Scotia Offshore Petroleum Board
(CNSOPB)

And

Province of Nova Scotia
represented by
Nova Scotia Department of Environment and Labour
(Province)

Background

The Environmental Studies Research Funds (ESRF) is a research program that sponsors environmental and social studies. ESRF is designed to assist government decision-making related to oil and gas exploration and development on Canada's frontier lands. The ESRF program has a legislated mandate under the Canada Petroleum Resources Act (CPRA). The ESRF is overseen by a joint government/industry/public Management Board and administered by a secretariat located in the National Energy Board office in Calgary, Alberta. An MOU between the Environmental Studies Research Funds Management Board and Environment Canada−Atlantic Region has been signed regarding the project *Airshed Monitoring on Sable Island* having a value of $100,000 (see attachment 1).

Project

The Project involves the acquisition, installation, calibration, operation and maintenance of air monitoring equipment that meets or exceeds the standards of the National Air Pollution Surveillance (NAPS) Network and withstands the rigours of the Sable Island environment. Data will be reported to the NAPS System—where final quality assurance and quality control will ensure data integrity and where the data will be made available to all interested parties. The monitoring will be valuable for the validation of pollutant models, end point impact, pollutant concentration trends and exposures at the Sable Island site. The time period for this project will be four years after which an evaluation will take place to consider continuation.

Purpose

The purpose of these Terms of Agreement is to serve as an adjunct to the signed MOU between ESRF and Environment Canada−Atlantic Region regarding *Airshed Monitoring on Sable Island,* (attachment 1) and to provide feedback to industry so as to promote continuous improvements. It is intended to facilitate an understanding of the financial and in-kind commitments of each party over the present four-year life span of this project. The parties, through the technical committee, will participate in the acquisition, setting up and calibration of the monitoring equipment on Sable Island, including the agreed operation and maintenance costs over the life of the project of four consecutive years beginning in the 2002−2003 fiscal year.

Equipment Acquisition Using ESRF Funds (see attachment)

Monitoring equipment to be acquired for the purposes of this project will include the following:

NOx: Continuous monitoring that meets or exceeds NAPS Standards
SOx/H_2S: Continuous monitoring that meets or exceeds NAPS Standards
Fine Particulate Matter (PM 2.5): Continuous monitoring − MetOne system

The technical advisory committee will ensure compliance with calibration standards and maintenance schedules and ensure that data are reported to the NAPS system and made available to others. Quality assurance and quality control of the data will be done initially by ARQB and protocols for NAPS will be followed.

The equipment will be retained by Environment Canada. Wherever possible, the technical committee will endeavour to facilitate the addition of new monitoring equipment.

Technical Advisory Committee

The parties and their representatives may change from time to time, but the Technical Advisory Committee is composed at present of representatives from the following:

Environment Canada

Meteorological Service of Canada: Chair, David Waugh
Environmental Protection: Bill Horne, Christine Garron
Environmental Technology Centre: Richard Turle
Air Quality Research Branch: Doug Worthy
Sable Island Preservation Trust: Scott James, Gerry Forbes
Canada-Nova Scotia Offshore Petroleum Board: Vince Gagner

Province of Nova Scotia, Nova Scotia Department of Environment and Labour: Michael Hingston
Canadian Association of Petroleum Producers: Geoff Hurley (EnCana Corporation)

In addition, the following three working groups have been set up under the auspices of the Technical Advisory Committee:

Working Group on Equipment Selection and Procurement: Michael Hingston, Chair, with input from others and consultations with Dr. Walker.
Working Group on Installation, Calibration, Operation and Maintenance: Gerry Forbes, Chair, with input from others as required.
Working Group on Ambient Air Reporting: Vince Gagner, Chair, with input from others as required.

Deliverables

Preface

Environment Canada−Atlantic Region, upon the recommendation of the Technical Advisory Committee, will purchase the above-mentioned equipment (where appropriate under a NAPS Standing Offer through the Environment Canada Headquarters). Environment Canada−Atlantic Region and the Technical Advisory Committee, possibly through a contractor, will also ensure that the equipment is set up and calibrated as per the NAPS protocols. Environment Canada will be the lead partner for the four-year commitment to the project.

Annual operation and maintenance costs will be shared between Environment Canada and CAPP throughout the four-year study. The Trust, the Province and ETC, and Environment Canada are all providing in-kind support.

The Province will provide in-kind support by providing a technical expert to draft the specifications and install, calibrate, operate and maintain the monitors over the life of the project. It is expected that there will be a need for periodic visits to Sable Island lasting approximately four days each.

Environment Canada's Environmental Technology Centre (ETC) will assume operations and maintenance costs as specified below. The ETC also agrees to provide assistance for the purchase of equipment and for the initial installation and calibration of this equipment. In the view of the ETC, the concept of Sable Island air monitoring must be as close as possible to that of a NAPS site.

Data will be made available on a near-real-time basis through the ARQD website. This method will be used to transmit data on all of the other compounds being monitored in connection with the ESRF.

The Sable Island Preservation Trust (SIPT) will provide operational facilities and technical assistance on Sable Island for the monitoring of equipment maintenance and operation, including data handling.

Annual Commitments of the Parties

Partners	Commitments	Comments
Sable Island Preservation Trust (The Trust)	Administrative Support 3hrs/wk labour costs (in-kind)	$14,000/yr for labour for preliminary data handling and equipment maintenance/upkeep. Data sets to be submitted to NAPS.
MSC–Atlantic	$5,000/year for O&M	Facilitation and co-ordination
EP−Atlantic	$5,000/year for O&M	Facilitation and co-ordination
CAPP	$10,000/year for O&M	Facilitation: skid and satellite dish delivery to Sable Island*
ETC–NAPS (Environmental Technology Centre and National Air Pollution Surveillance)	$10,000/year for O&M	Technician to provide support for initial equipment set-up and calibration. Final data sets available through NAPS (in-kind)
NSDEL	Set-up and calibrations	Technician to go to Sable Island twice a year (in-kind)
CNSOPB	Facilitation	
ARQD	CH4 CO CO2 set-up Data display (near-real time) on Web Loan of MD9s and 2 data loggers as required. Value of $10,000	Maintenance of this equipment (in-kind)

Total: $30,000

*To assist the committee, EnCana Corporation is providing the expertise of Dr. Walker (Jacques Whitford)

Purchases Using ESRF Funds to Date

Item	Capital Cost	Comments
NOx Analyser	~$22,000	
SOx Analyser	~$18,000	
Air Monitoring Building (Shed)	~$25,000	Obtained from RSLS Environet, Calgary
PM	~$25,000	Selection and Procurement WG currently determining best option

Annual O&M Disbursements

O&M	Annual Cost	Item	Comments	Paid To
Electricity	$17,000/year	At $1.48/kwh		The Trust
Consumables	$3,000/year	Filters, calibration gases, pumps, lamps		Suppliers as required
Shipping Costs	$1,000/year	Mail, courier, transport		The Trust and Suppliers as required
Annual Visit	$6,000/year, 2 flights $2,000/year for accommodation	For calibrations, etc.	Based on splitting cost of a charter flight; 2 people for 4 days	The Trust and the transport company

Total: $29,000/year

IN addition, opportunities to add additional monitoring equipment at a minimal cost will be considered. A hydrogen sulphide (H_2S) monitor is included with the SOx monitor.

<u>Title: Beneficiaries of the Monitoring</u>

What We Will Monitor	Equipment Cost	Labour Cost/ Supplier	Data Handling	Who Will Benefit
NOx	~$22,000	NAPS Supply	ARQD	CAPP, EC, NSDEL,* CNSOPB
SOx	~$18,000	NAPS Supply	ARQD	CAPP, EC, NSDEL,* CNSOPB
Particles – PM	~$2,000	MetOne instrument or compatible	The Trust	CAPP, EC, NSDEL,* CNSOPB

Total: ~ $65,000 *Benefit to NS for Transboundary and Long-Range Transport Studies

NB: As a consequence of the ESRF Air Monitoring Station Project, additional complimentary monitoring of Methane (CH4), CO and CO_2 will be provided through AQRD, while the ozone monitoring unit will be available from NAPS.

<u>Payment</u>

The partners mentioned above will be invoiced by Environment Canada on an annual basis for their commitments at the beginning of each fiscal year (e.g., 2002−2003 FY). The electricity charges and accommodation charges will be paid to the Trust upon invoicing for same. In the event of significant changes in the O&M costs, this agreement may be reassessed.

Financial Records/Audit

Environment Canada commitments are indicated below.

O&M TERMS AND CONDITIONS

Definitions

Unless the context requires otherwise,

“Minister” means the Minister of Environment Canada and includes any person duly authorized to act on behalf of the Minister;
“Department” means the Department of Environment Canada;
“Party” means the party signing this agreement;
“Agreement” means the Agreement, the “General Conditions” and such amendments and agendas that are or may be expressed to form part of the Agreement;
“Government of Canada” means Her Majesty the Queen in Right of Canada.

Public Acknowledgment

Any information released or announced to the public concerning the subject matter of this Agreement must appropriately acknowledge the contribution made by the Government of Canada.

Conflict of Interest

The Party must at no time during the term of this Agreement pursue interests served by this Agreement.

Legality

The recipient must ensure that the activities or programs will be conducted in compliance with all applicable laws.

Liability

Her Majesty must not be held liable for injury, including death to persons, or for the loss of or damages to the property of the Party, or of anyone else, occasioned by or in any way attributable to the Party under this Agreement, unless such injury, loss or damage is caused by the negligence of an officer or agent of Her Majesty acting within the scope of his/her employment.

Joint and Several Obligations

Where an organization is not a corporation or a legal entity, any person who signs this Agreement for any non-governmental environmental organization, must be held jointly and severally liable for any and all obligations under this Agreement.

Notice

Any notice to the Party must be effectively given if sent by letter, telex or telegram, postage prepaid or with charges prepaid as the case may be, addressed to the Recipient at the address shown in the records of the Minister. Any notice so given shall be deemed to have been received by the Party at the time when, in the ordinary course of events, such a letter, telex or telegram would have reached its destination.

Audit

The Minister reserves the right to audit or cause to have audited the accounts and records of the Party to ensure compliance with the terms and obligations of the Agreement and the Party must make available to such auditors any records, documents and information that the auditors may require. The scope, coverage and timing of such audits must be as determined by the Minister and, if conducted, may be carried out by employees of the Department or its agent(s).

Intellectual Property

Intellectual property created by the Party with the funds received under this Agreement remains with the Party, provided that the Party hereby grants to the Department the licensed rights to produce, publish, translate, reproduce, adapt, broadcast or use at no cost any work subject to such intellectual property rights.

Equipment

All equipment purchased in connection with the project with funds from the Party shall remain the property of Environment Canada, except where specifically noted in this Agreement.

Signatures

____________ ________ Bill Appleby Date Environment Canada, Atlantic Region	____________ ________ David Luff Date Canadian Association of Petroleum Producers
____________ ________ Scott James Date Sable Island Preservation Trust	____________ ________ Jim Dickey Date Canada-Nova Scotia Offshore Petroleum Board
____________ ________ Bob Langdon Date Nova Scotia Department of Environment and Labour	____________ ________ Richard Turle Date Environmental Technology Centre
____________ ________ Maris Lusis Date Air Quality Research Branch	

Appendix D − Measurement Instrument Operating Parameters

Fine-Particulate Monitor	
Make/Model	Metone BAM 1020
DOE Number	J39195
Serial Number	B-5256
EEPROM	Version 2.55
Range	0.250 mg
Analog Output Range	0–5 vdc (no offset)
BAM Sample	50 minutes
Flow Rate	16.7l pm
Flow Type	STD (data reported at 25°C, 760 mm Hg)
Alarm, Flow Rate High	22l pm
Alarm, Flow Rate Low	15l pm
Cycle Mode	Early

SO2/H2S Analyser	
Make/Model	Teledyne-API 101A
DOE Number	J39161
Serial Number	400
Range	0−500 ppb (should be 0−500 ppb)
UV Lamp	≥ 70% (100% @ ~ 3,500 mV)
Sample Flow	650 ccm/min ± 65
Reaction Cell Temperature	50°C ± 1°C
PMT Temperature	7°C ± 1°C
IZS Option	
Permeation Oven Temperature	50°C ± 0.3°C
Permeation Tube Make	Dynacal
Permeation Tube Size	40F3 (should be 40F3)
Permeation Tube Part Number	150-643-0110 ML
Permeation Rate	76 ng H_2S/min @ 50°C ± 25%
Zero Air Scrubber	Activated charcoal

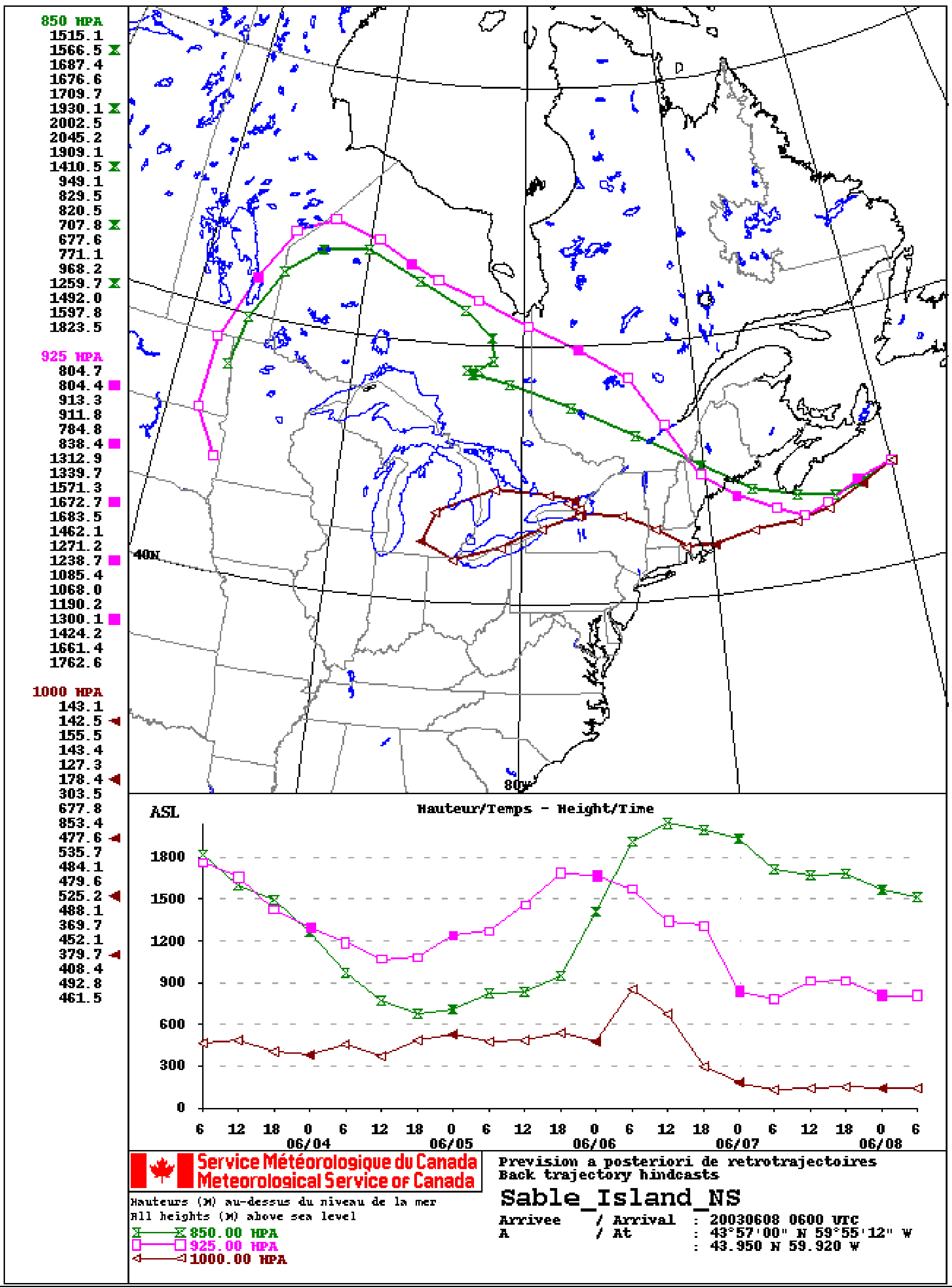
NOx Analyser	
Make/Model	API 200A
DOE Number	J39158
Serial Number	2269
Range	0−1,000 ppb
Sample Flow	500 cc/min ± 50
Ozone Flow	60 to 90 cc/min
Reaction Cell Temperature	50°C ± 1°C
Reaction Cell Pressure (external pump)	5 ± 1 in-Hg
Photo-Multiplier Tube Temperature	7°C ± 1°C
Molybdenum Converter Temperature	315°C ± 5°C
Time	AST

Analog Output Range	0–5 vdc
IZS Option	
Permeation Oven Temperature	50°C ± 0.4°C
Permeation Tube Make	Dynacal
Permeation Tube Size	40F3
Permeation Tube Part Number	150-643-0081-ML-U50
Permeation Rate	790 ng NO_2/min @ 50°C ± 25%
Zero Air Scrubber	Purafil® / Activated charcoal

Ozone Analyser	
Make/Model	TEI 49C
DOE Number	N/A
Serial Number	49C-61607-332
Range	0−1,000 ppb
Averaging Time	60 seconds
Analog Output Range	0−1 vdc
Flow (through cells)	> 600 cc/min
Detector intensity	> 65,000 Hz

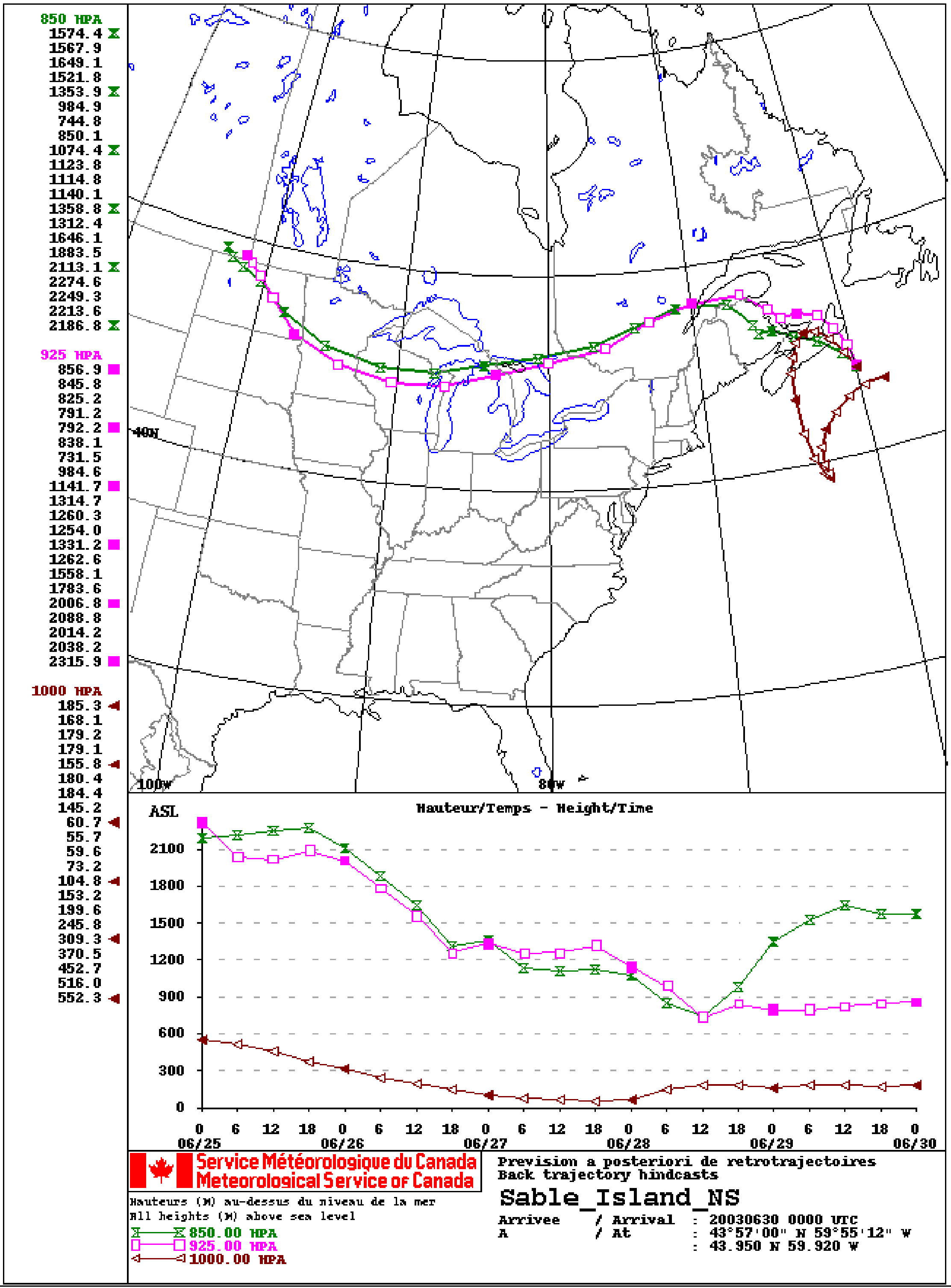
Appendix E: Back-Trajectories for Transboundary-Influenced Pollutant Events

E1: Back-Trajectory for Long-Range Transport Ozone Event, June 7-9, 2003



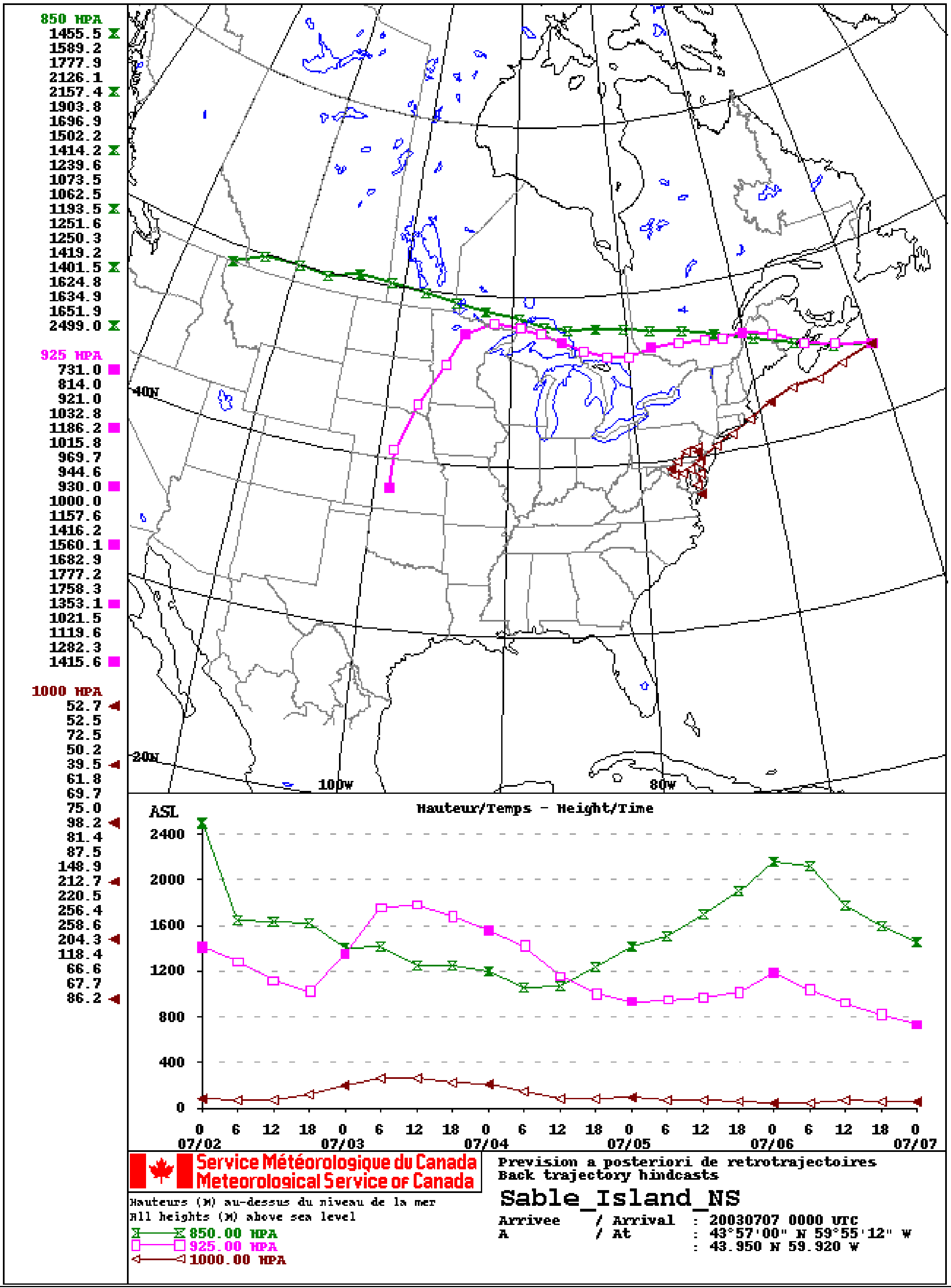
120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 0600UTC, June 8, 2003

E2: Back-Trajectory for Wide-Scale Regional Transboundary $PM_{2.5}$ Event, June 29-30, 2003



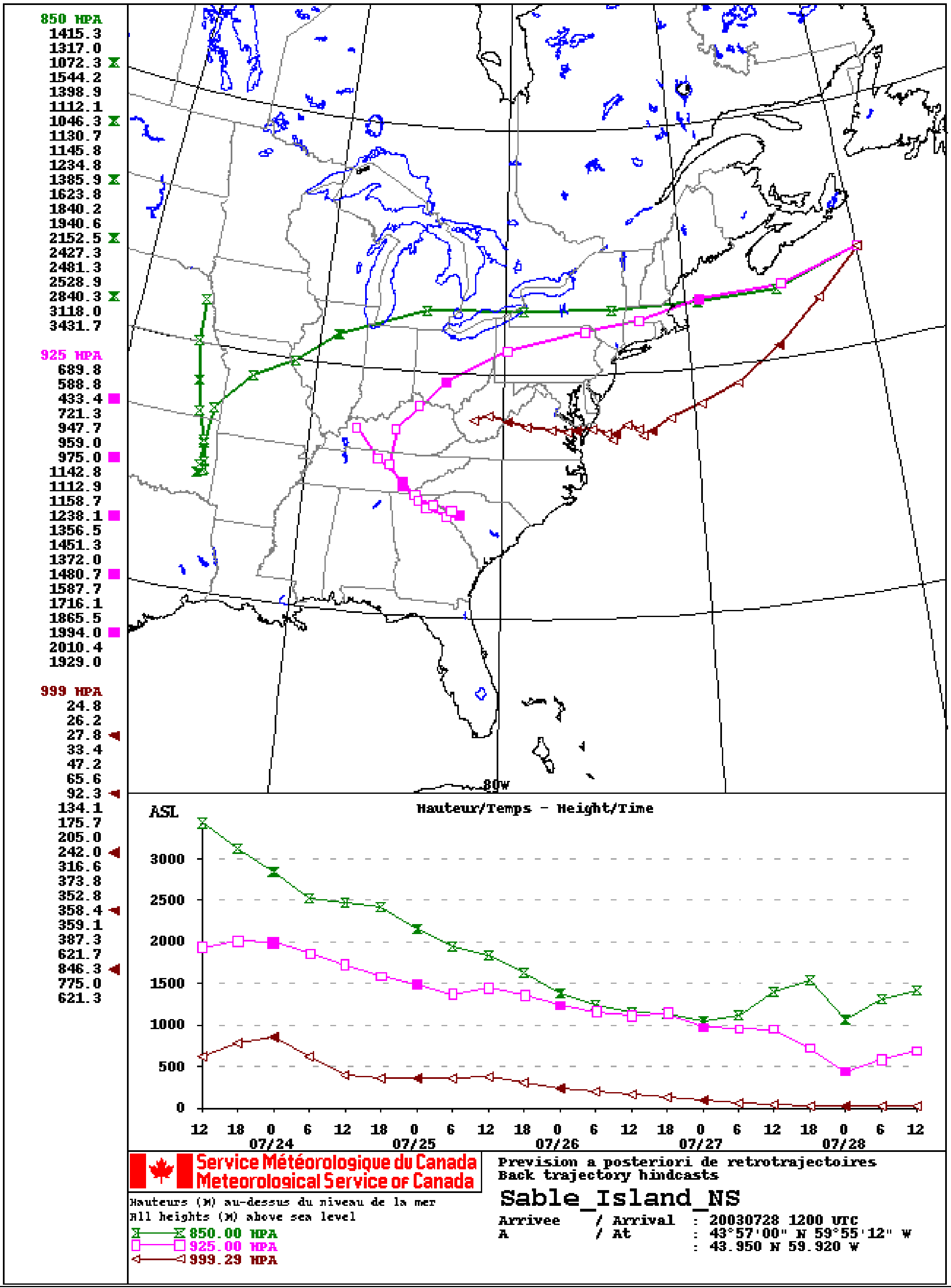
120-hour back-trajectories for Sable Island arriving at 1,000, 925 and 850 hPa levels, valid 0000 UTC, June 30, 2003

E3: Back-Trajectory for Wide-Scale Regional $PM_{2.5}$ Event, July 6-7, 2003



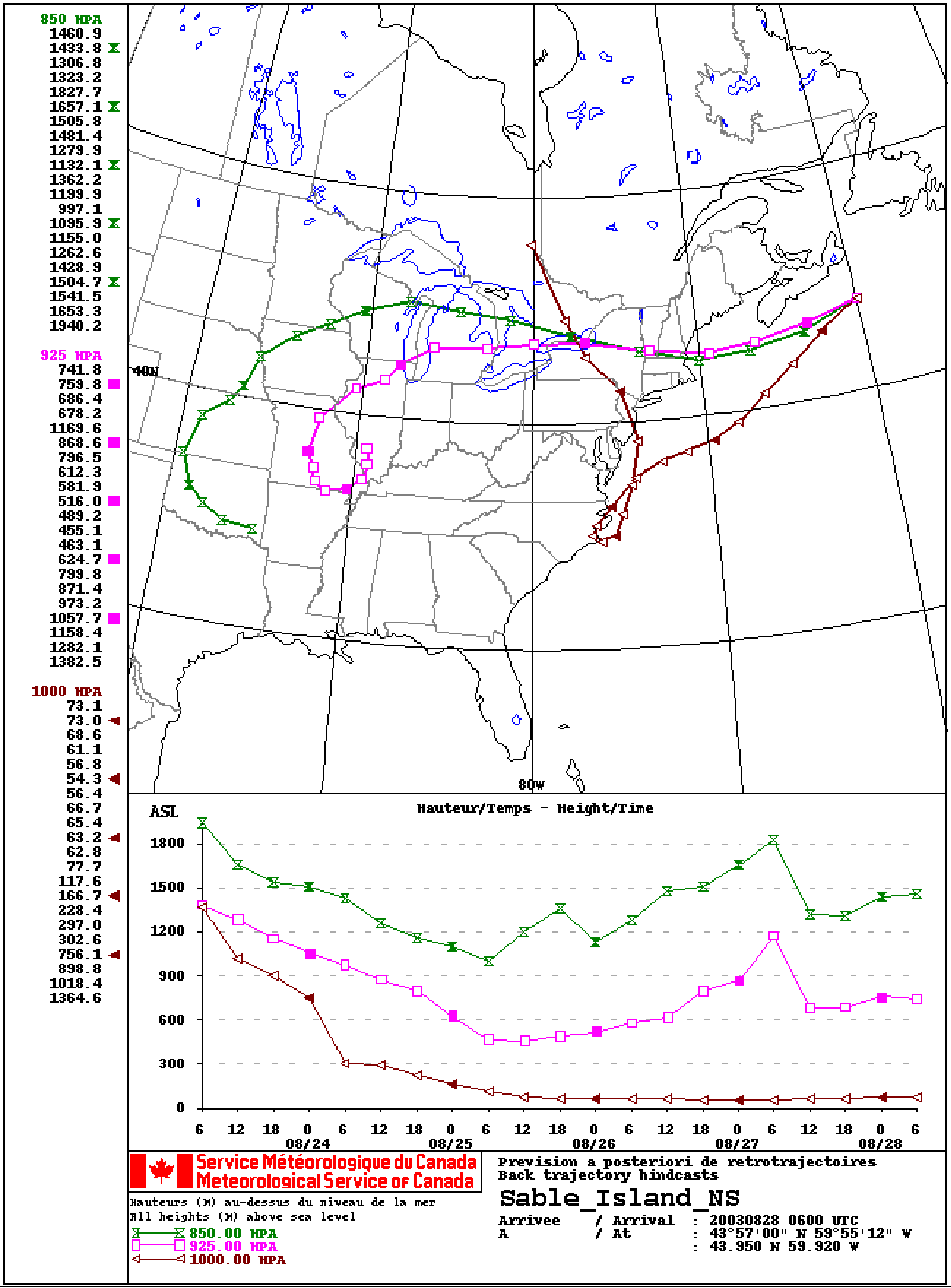
120-hour back-trajectories for Sable Island arriving at 1,000, 925 and 850 hPa levels, valid 0000 UTC, July 07, 2003

E4: Back-Trajectory for Regional/Transboundary $PM_{2.5}$ Event, July 27-28, 2003



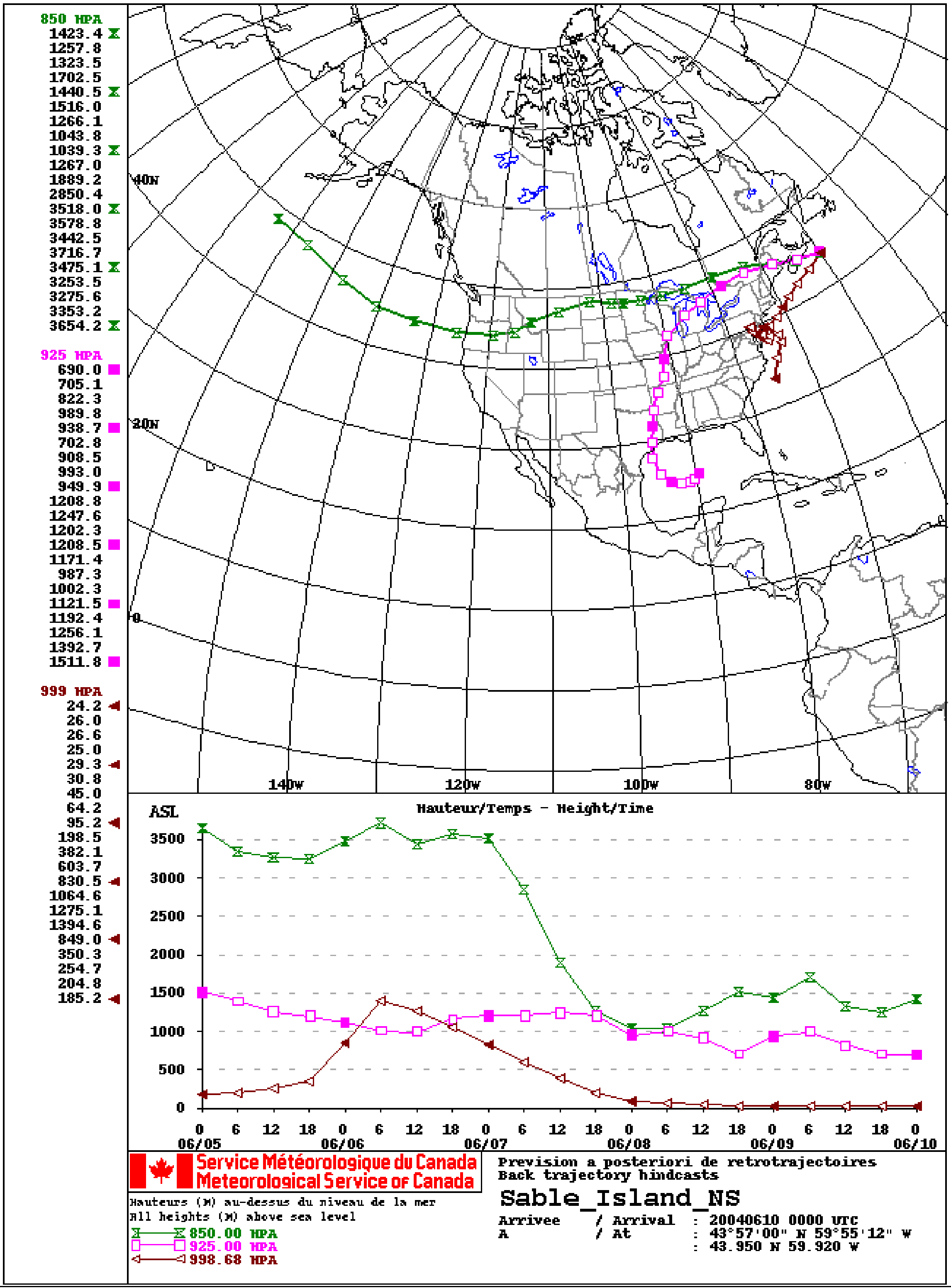
120-hour back-trajectories for Sable Island arriving at 999, 925 and 850 hPa levels, valid at 1,200 UTC, July 28, 2003

E5: Back-Trajectory for $PM_{2.5}$ Event, August 27-28, 2003



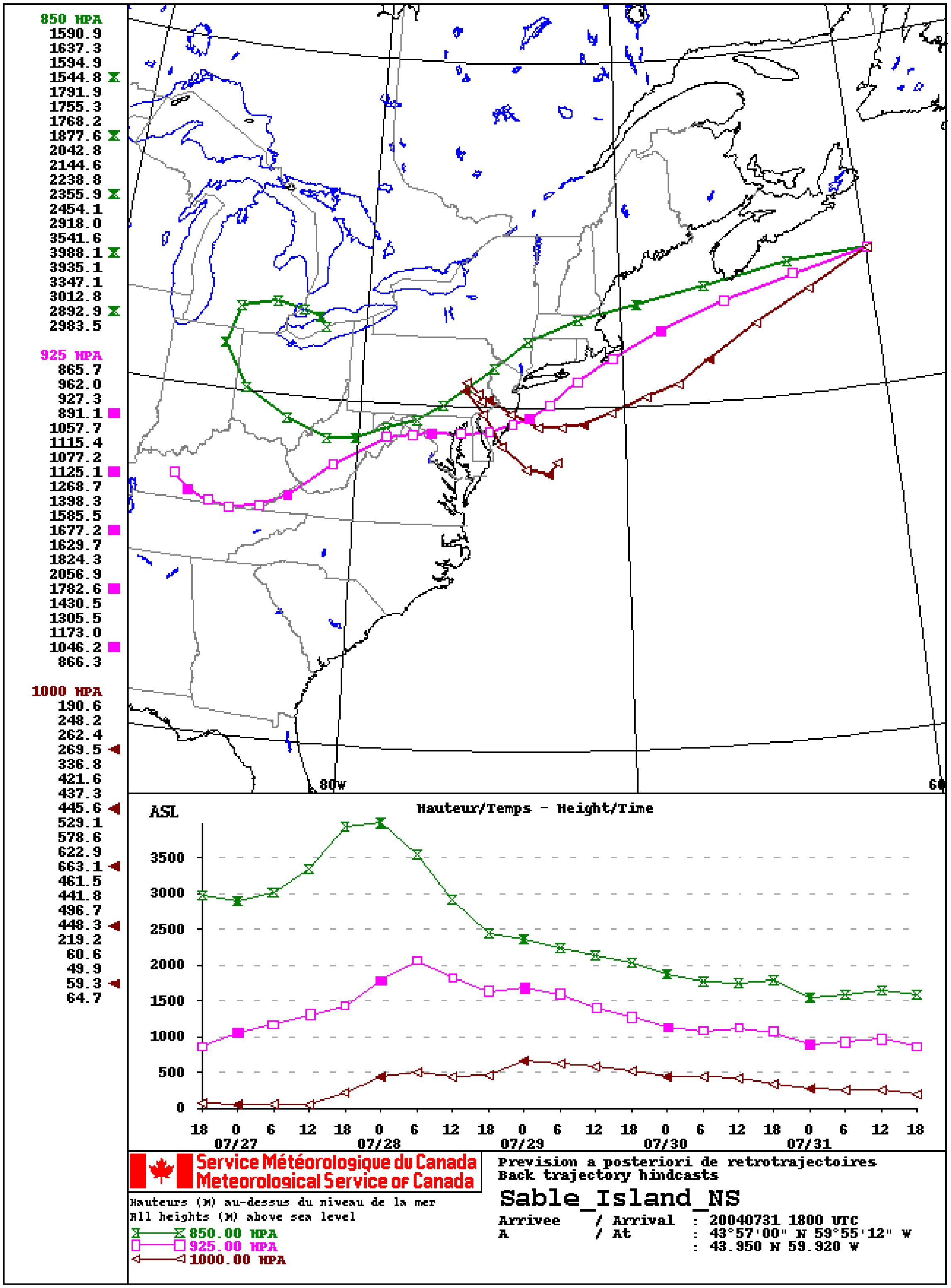
120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 0600UTC, August 28, 2003

E6: Back-Trajectory for Long-Range Transport $PM_{2.5}$ Event, June 9-10, 2004

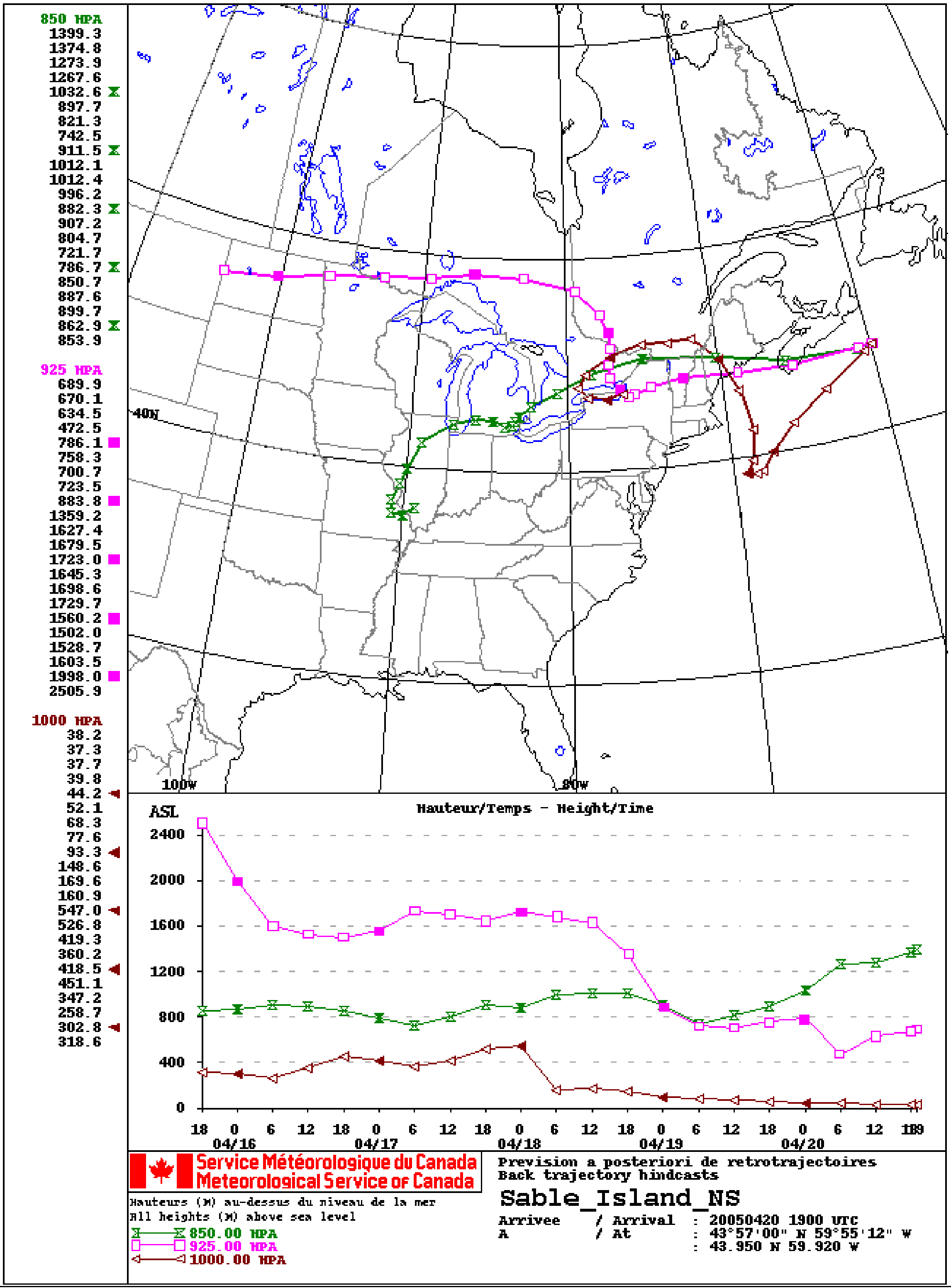


120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 0000UTC, June 10, 2004

E7: Back-Trajectory for Long-Range Transport Ozone Event, July 31, 2004

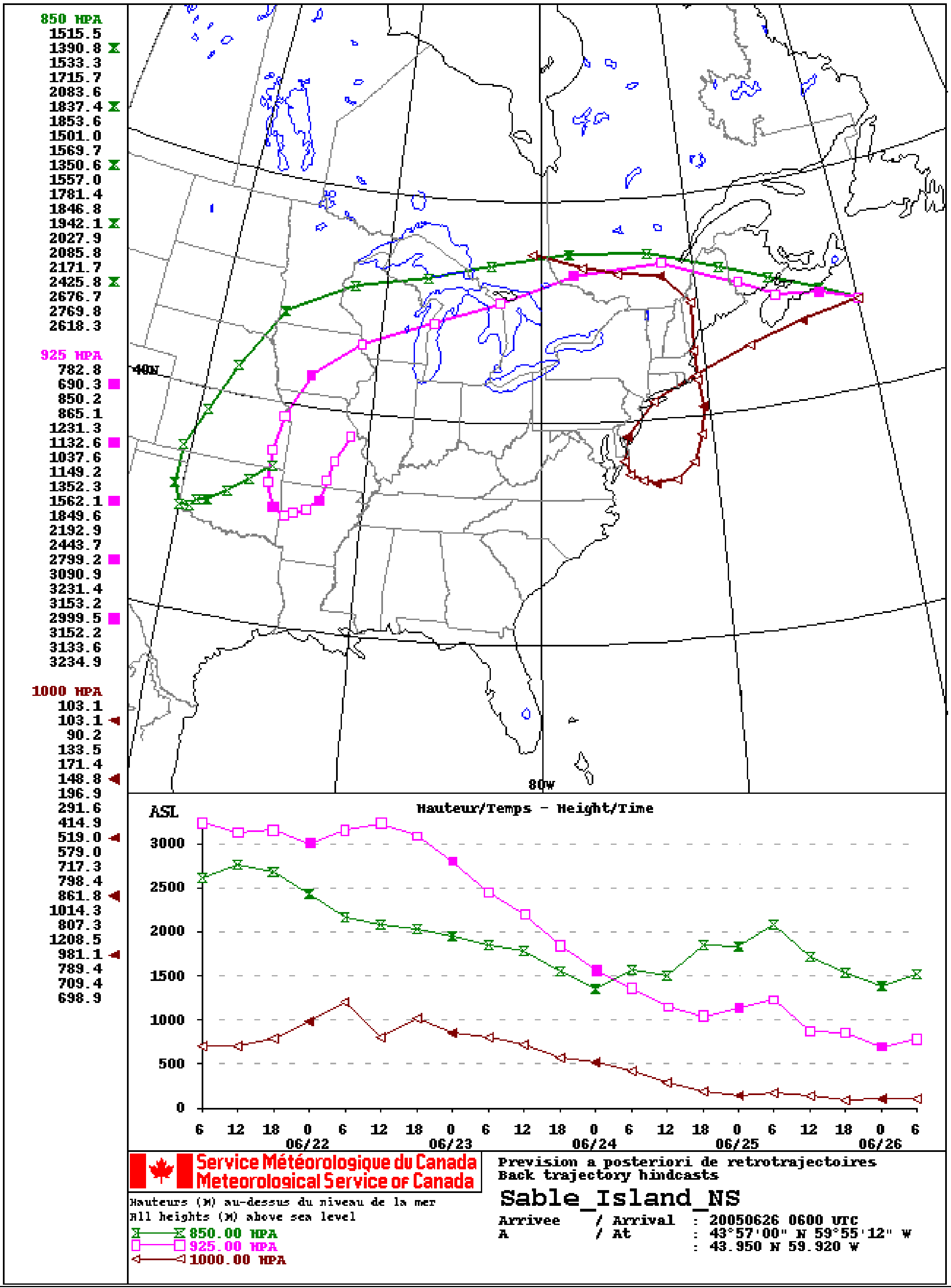


E8: Back-Trajectory for Long-Range Transport Ozone and $PM_{2.5}$ Event, April 20-21, 2005



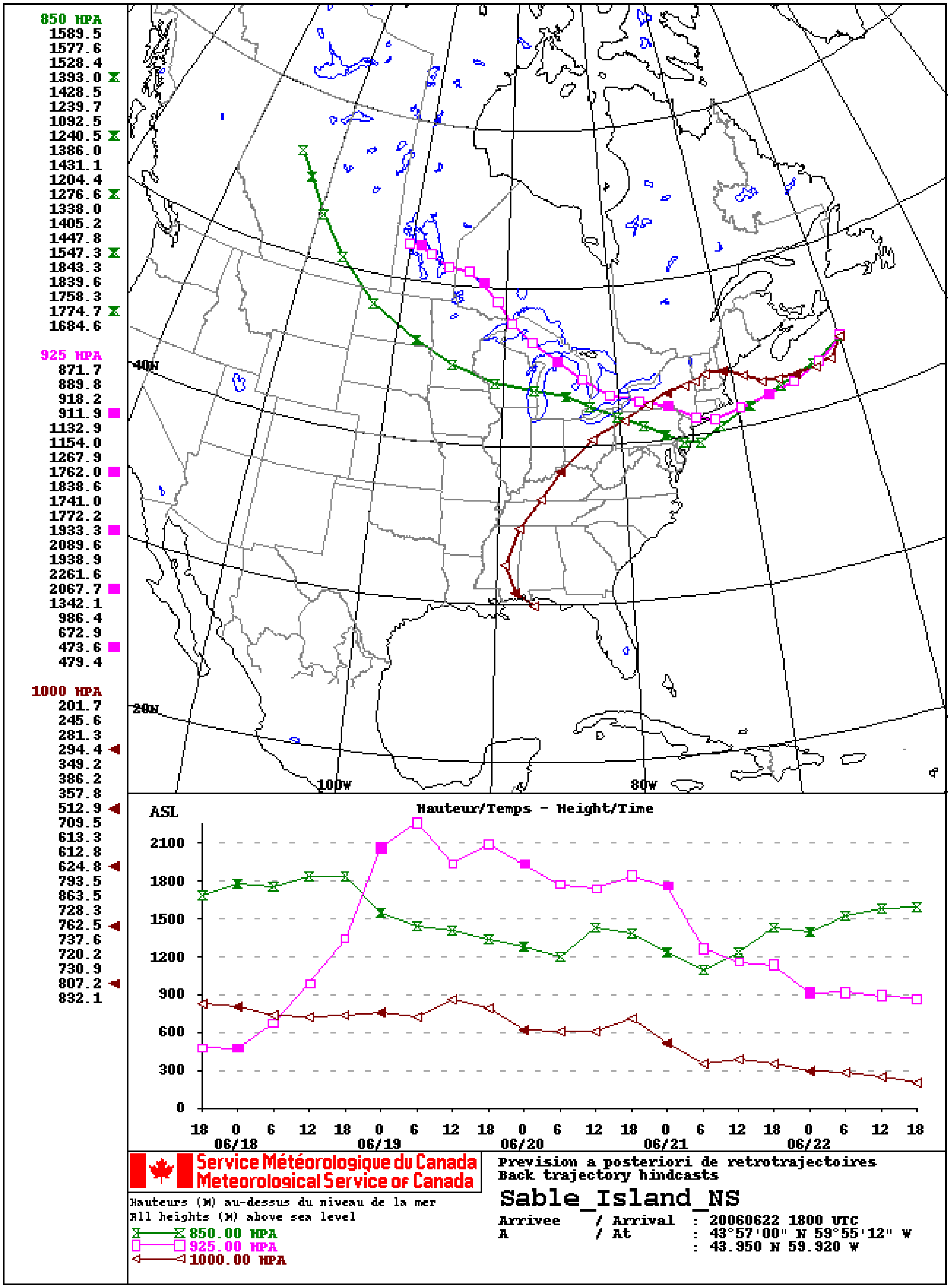
120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 1900UTC, April 20, 2005

E9: Back-Trajectory for Long-Range Transport $PM_{2.5}$ Event, June 26, 2005



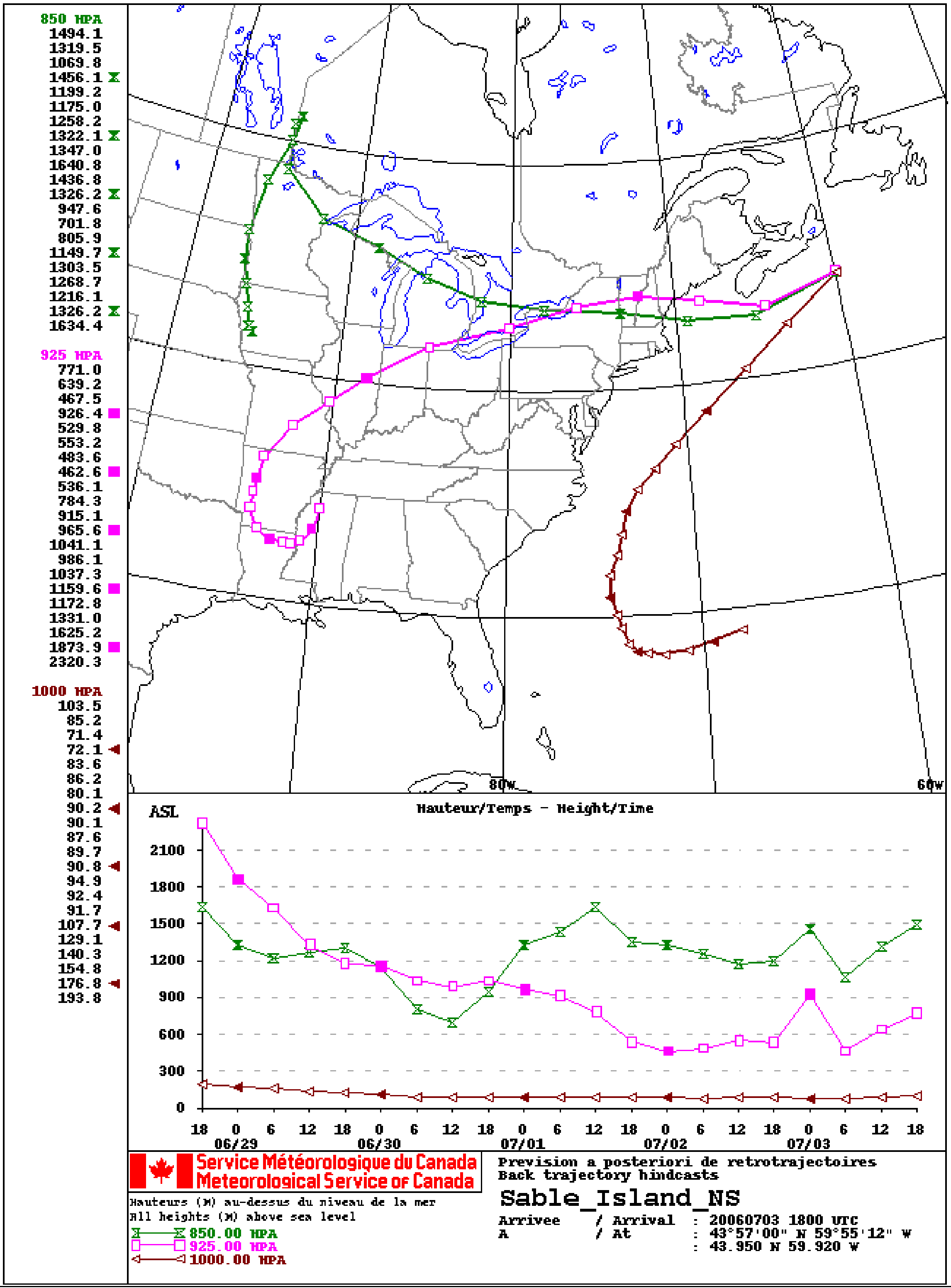
120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 0600UTC, June 26, 2005

E10: Back-Trajectory for Long-Range Transport Ozone Event, June 21-22, 2006



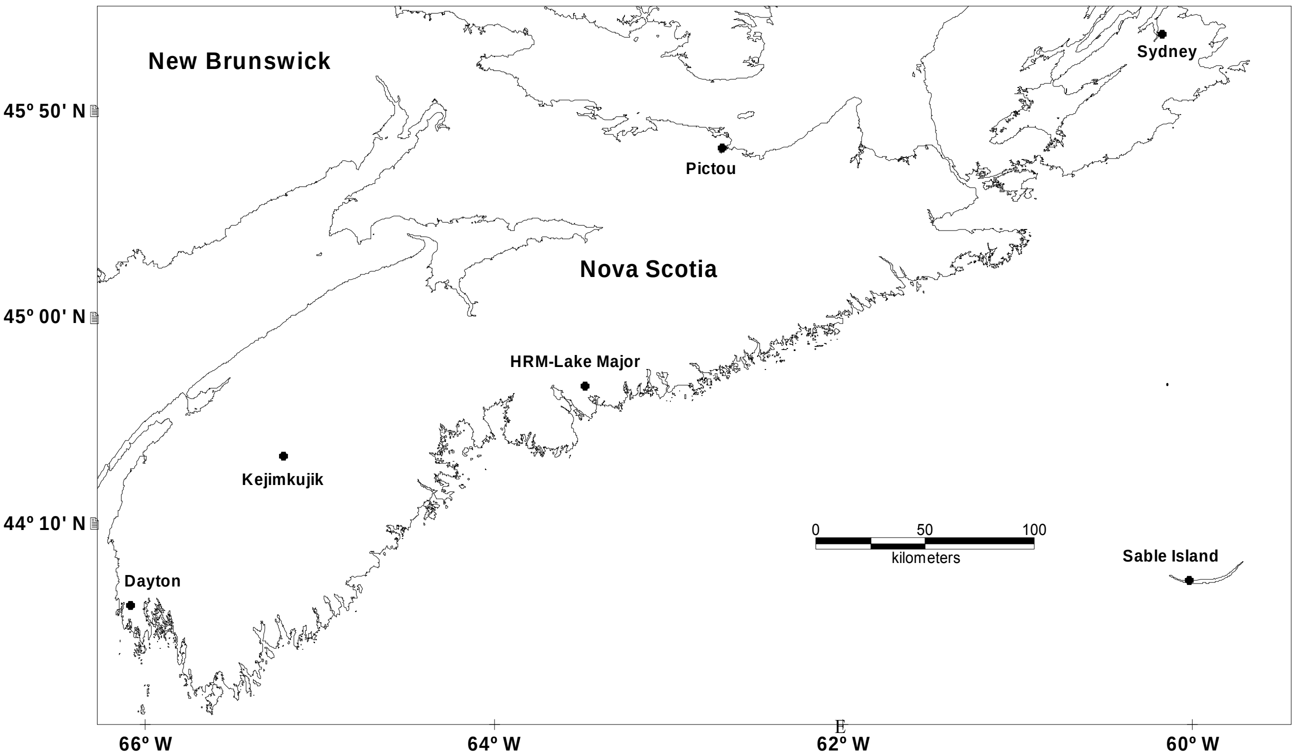
120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 1800UTC, June 22, 2006

E11: Back-Trajectory for Long-Range Transport Ozone and $PM_{2.5}$ Event, July 2-3, 2006



120-hour back-trajectories for Sable Island at the 1,000, 925 and 850 hPa levels, valid 1,800UTC, July 03, 2006

Appendix F – Nova Scotia NAPS sites



Appendix G – Storm Data Comparisons

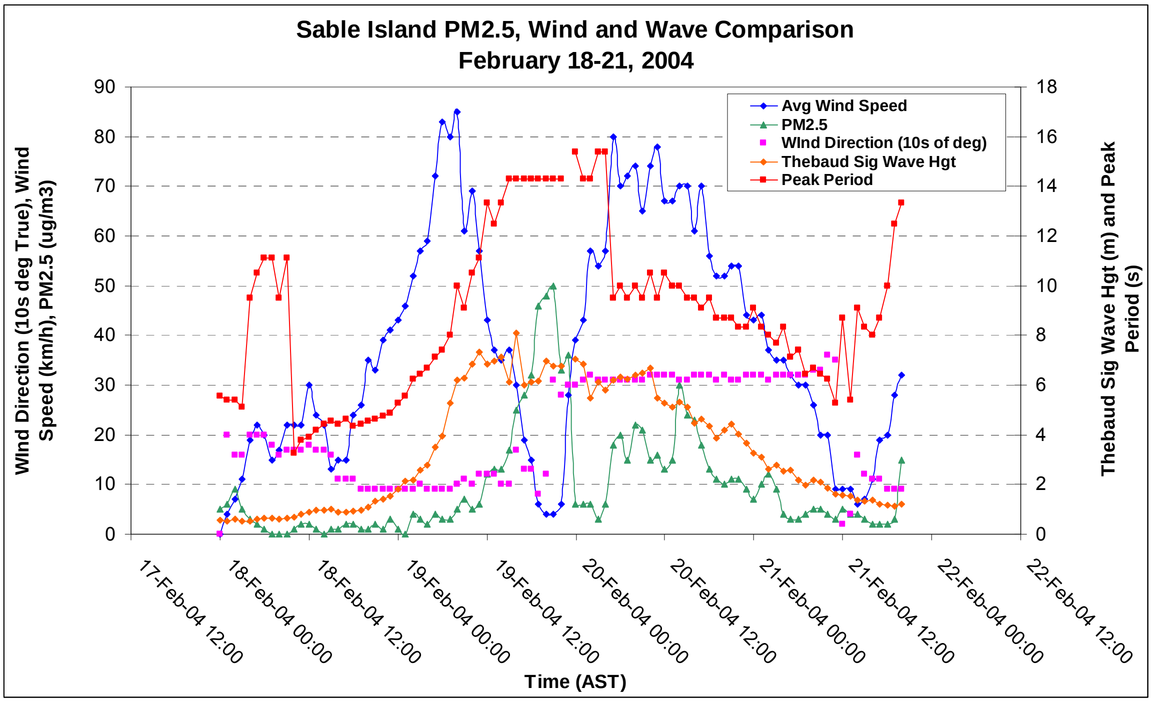


Figure G1: Graph of the Sable Island $PM_{2.5}$ (BAM) (green) hourly concentrations for February 18−21, 2004 during the passage of an intense winter storm. Comparison data for wind direction (magenta) and speed (blue) from Sable Island as well as Thebaud platform significant wave height (orange) and peak period (red) are also indicated. The maximum PM2.5 concentrations occurred during a period of light winds, high significant wave heights and high peak wave periods.

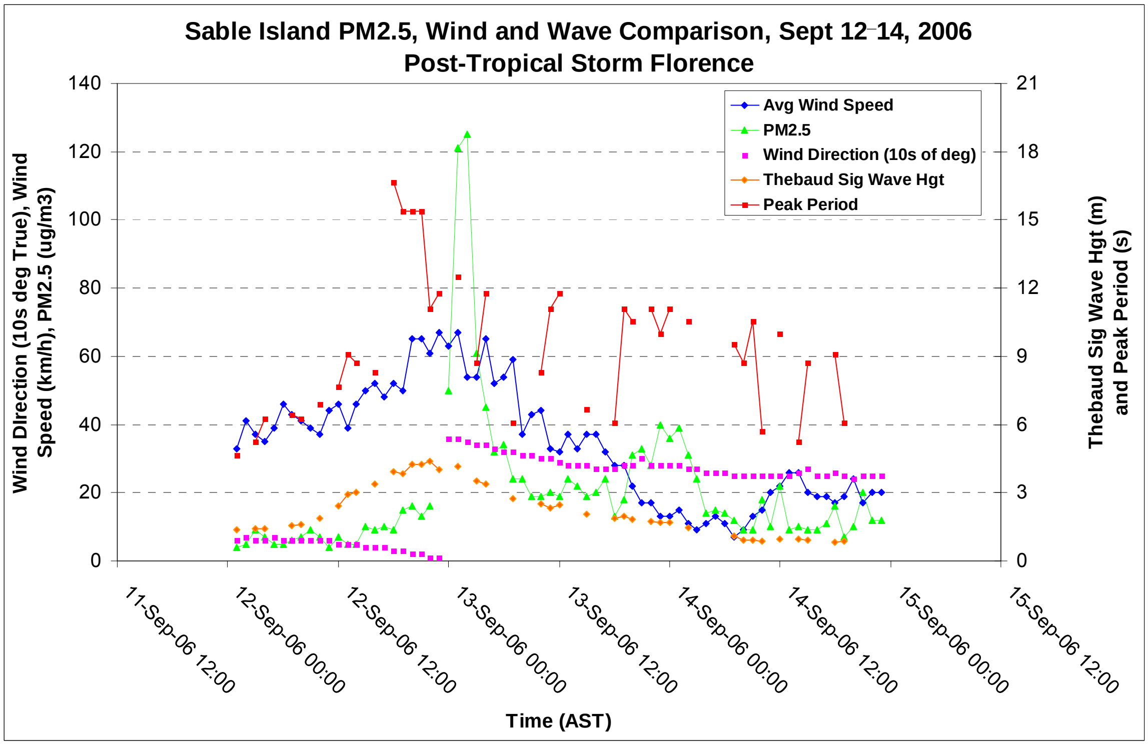


Figure G2: Graph of the Sable Island $PM_{2.5}$ (BAM) (green) hourly concentrations for September 12–14, 2006 during the passage of post-tropical storm Florence. Comparison data for wind direction (magenta) and speed (blue) from Sable Island as well as Thebaud platform significant wave height (orange) and peak period (red) are also indicated. The maximum concentrations occurred when winds were from 360 degrees and winds were at their maximum speed.

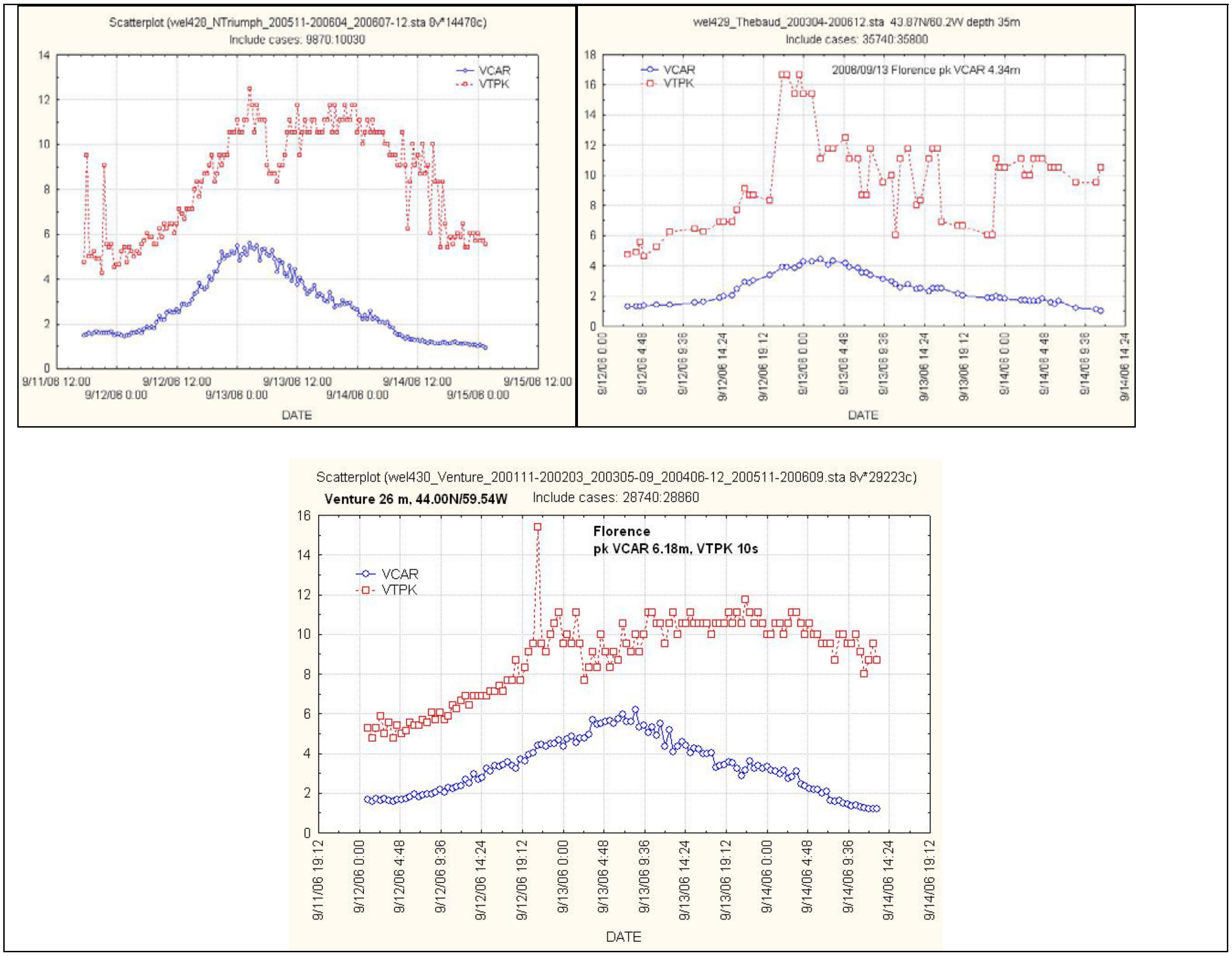


Figure G3: Significant wave heights (m) in blue and maximum wave heights (m) in red for the North Triumph (68-m depth), the Thebaud (35-m depth) and North Venture (26-m depth) platforms for the September 11–14, 2006 period. Post-tropical storm Florence was at its closest approach early on the day of September 13. (Credit: Bridget Thomas, Environment Canada)

Appendix H – Sable Island Air Monitoring Program Committee

Canada-Nova Scotia Offshore Petroleum Board	Elizabeth Macdonald Eric Theriault
Canadian Association of Petroleum Producers	Paul Barnes Aurora Reid
Encana	Marielle Thillet
Environmental Studies Research Fund	Robert Steedman
Environment Canada	Gerry Forbes Michael Hingston Tracey Inkpen Stephanie Keast Jayne Roma
Exxon-Mobil	Greg Macdonald Cal Ross Megan Tuttle
Meteorological Service of Canada	David Waugh Doug Worthy
Nova Scotia Environment	Barb Bryden Fran Di Cesare Johnny McPherson