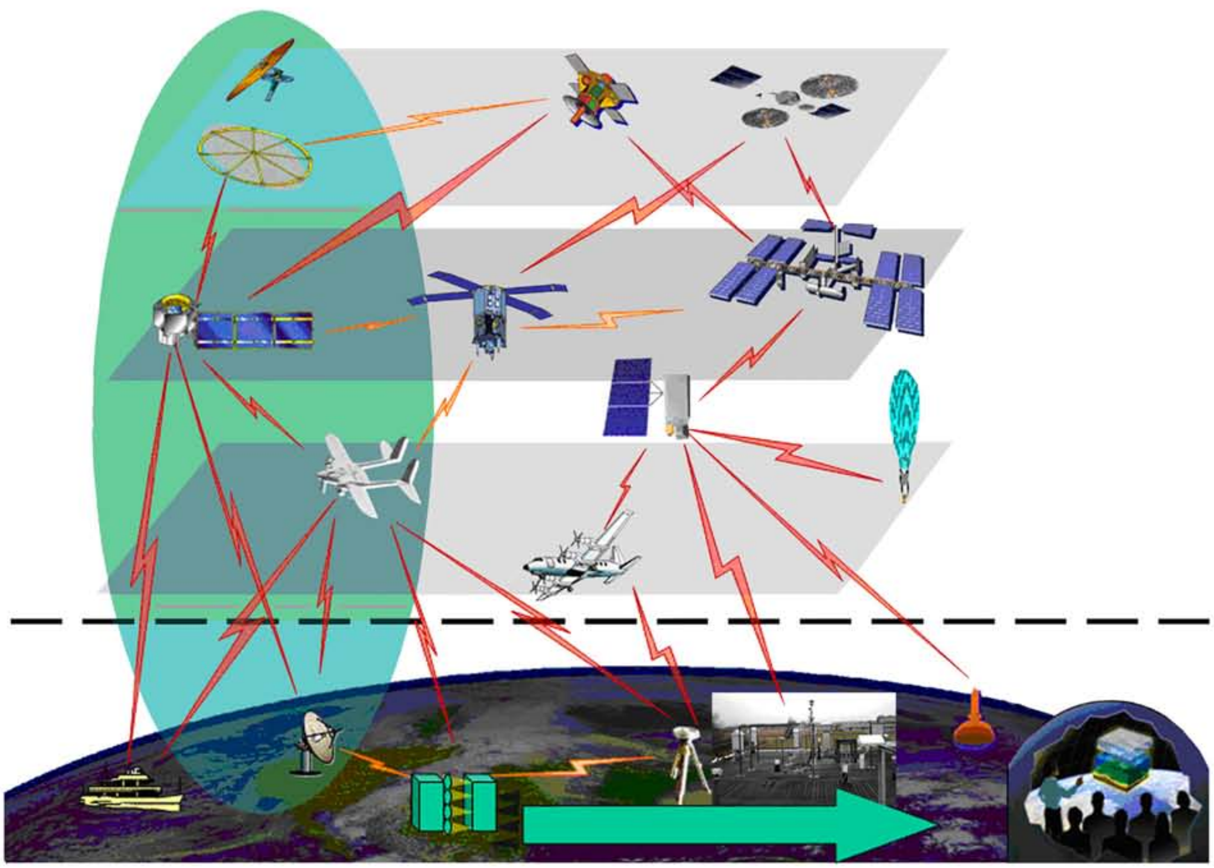
SUMMARY REPORT

Second Clean Areas Workshop:

Exploring Collaborative Opportunities in Air Quality Monitoring, Modelling and Communication

December 2005

Report from the International Air Quality Advisory Board to the International Joint Commission



INTERNATIONAL JOINT COMMISSION
Canada and United States

COMMISSION MIXTE INTERNATIONALE
Canada et États-Unis

SUMMARY REPORT

Second Clean Areas Workshop:

Exploring Collaborative Opportunities in Air Quality Monitoring, Modelling and Communication

Workshop held March 22 – 23, 2005
David Skaggs Research Center
National Oceanic and Atmospheric Administration Building
Boulder, Colorado

December, 2005

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Report from the
International Air Quality Advisory Board
to the International Joint Commission

EXECUTIVE SUMMARY

With support from Environment Canada and the National Oceanic and Atmospheric Administration, the International Air Quality Advisory Board (IAQAB) of the International Joint Commission (IJC) hosted a second workshop exploring collaborative opportunities in air quality monitoring, modelling and communication. Practically all the examples and illustrations cited in this report are drawn from presentations made at the workshop; these are available through the Great Lakes Regional Office of the International Joint Commission.

The workshop explored three themes; an examination of ground-based air quality monitoring in the United States (U.S.) and Canada, particularly in the transboundary region, and the possibility of co-location of selected sampling equipment; the application of remote sensing technology to air quality measurement, modelling and management; and the development of air quality indices and related air quality forecasting technology and related use in public communication plans.

Encouraging progress on the installation of equipment used in the U.S. IMPROVE program to measure fine particulate and related contaminants at a site in Ontario was discussed as part of an overview of monitoring networks both routine and specialized, in the U.S. and Canada, including the jointly operated Integrated Atmospheric Deposition Network. Commitment to the collocation project appears adequate to allow at least one joint station to become operational.

In a consideration of sources, some improvement in the characterization of the total loading of nitrogen species, including ammonia, particularly from agricultural operations, appeared to be timely. It was apparent that the impact of nitrogen enrichment on ecosystem health required more detailed consideration than it has received to date.

Selected examples of the application of remote sensing technology, largely satellite based, and their integration with ground based monitoring were reviewed. Such integration allows a more detailed and comprehensive view of phenomena such as forest fires, as well as the tracking of pollution from one continent to another. Further international collaboration in this area should be encouraged. Specifically, an extension of a joint academically operated LiDAR network to further sites in Canada was recommended, as well as development of a Canadian Smog Blog providing daily summaries of air quality in portions of Canada similar to the output of the U.S. Smog Blog.

The workshop also examined air quality communication strategies, including the evolution of air quality indices (AQI) and national and other programs to forecast air pollution incidents. Given the distinctions in the standards and guidance on individual pollutants in the two countries, AQIs, while similar, are not now nor will they become identical. Guidance on these differences may be necessary, particularly in the transboundary region.

Air quality forecasting for ozone is available on a routine basis in several regions of both countries and has been extended to particulate matter in some locales. Some U.S. National Parks provide this service and its extension to Canadian parks was recommended.

Workshop participants also advocated the continuing but selective oversight by the IJC in air quality research in the U.S. and Canada, mindful of the several other bodies working in this area. Some extension of the examination of ecosystem health impacts, such as forest sensitivity mapping, and the continuation of this workshop series with the participation of local, state, provincial and federal personnel were both advocated.

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APPENDICES

1.0 INTRODUCTION

With the support of Environment Canada and the National Oceanic and Atmospheric Administration (NOAA), the International Air Quality Advisory Board (IAQAB) of the International Joint Commission (IJC) hosted its Second Clean Areas Workshop – *Beyond Keeping Clean Areas Clean and Prevention of Significant Deterioration: Exploring Collaborative Opportunities in Air Quality Monitoring, Modelling and Communications* – on March 22 and 23, 2005 at the David Skaggs Research Center, National Oceanic and Atmospheric Administration in Boulder, Colorado.

An underlying theme throughout the workshop was a continued emphasis on bilateral communication, co-operation and collaboration. While this second event explored the status of some of the recommendations from the first workshop held in Vancouver in February, 2004, the three selected themes extended the reach of this workshop significantly beyond those formulated at the first event. These three broad themes included:

1. An examination of ground-based air quality monitoring in the United States (U.S.) and Canada, particularly in the transboundary region, and an exploration of the possibility of co-location of selected sampling equipment and generation of parallel data sets for selected contaminants;

2. The application of remote sensing technology such as that associated with aircraft or satellites to air quality measurement, modelling and management; and

3. The development of air quality indices and related air quality forecasting technology and their use in public communication plans.

A number of U.S. and Canadian participants attended the workshop, including personnel from federal, provincial, state and municipal governments. A number of scientists, including specialists in ground-based monitoring, remote sensing and air quality forecasting experts, and policy makers and communication specialists also participated. A list of participants is attached as an appendix to the report.

This paper is intended to summarise the Boulder workshop, providing an opportunity for the IAQAB to comment on these issues. The Board will forward selected insights to the Commissioners of the IJC on the chosen themes and other salient issues raised at the workshop. Recommendations for future work are provided, including suggested roles for the IAQAB and the IJC on possible future activities and the means to pursue them over the longer term.

2.0 THEME 1: CO-LOCATION AND GROUND BASED AIR QUALITY MONITORING

2.1 Co-location

One of the key recommendations from the first workshop advocated the:

"Selection of a pilot project region in the border area for assembly of monitoring information and air quality data, identification of risks to the airshed, and development of recommendations for co-locating monitors, working toward a common plan."

To this end, a subcommittee of participants with expertise in monitoring networks in the two countries was established in advance of this workshop to focus on the issue of comparison between techniques and protocols used in the measurement of fine particulate matter concentrations in Canada and the U.S. This group is working in support of closer integration of U.S. and Canadian fine particulate monitoring efforts and, as a first step, has agreed to the co-location of instrumentation from both countries at Egbert, Ontario. Figure 1 and Figure 2 are photographs of this site.

Figure 1: Egbert CARE Monitoring Site Platform (Source: Pitchford presentation)

Figure 2: CARE Platform at Egbert Site (Source: Pitchford presentation)

An agreement arose whereby instruments from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network in the U.S. are to be installed at the Egbert site, with ongoing analytical and data processing support provided by the IMPROVE program. The Canadian Centre for Atmospheric Research Experiments (CARE) is also located in Egbert, ensuring the availability of station support personnel. In addition, a relatively low level of air pollution prevails at this site, which should allow comparability among instruments at low concentrations, a crucial aspect of the co-location program.

The IMPROVE network was established in 1985 in response to the 1977 U.S. Clean Air Act Amendments. U.S. Federal Land Management agencies responsible for Class I areas (156 National Parks and Wilderness Areas) joined the United States Environmental Protection Agency (U.S. EPA) in this collaborative program. The U.S. network consists of particulate matter monitoring devices placed at 110 sites within these areas, as well as selected extended sites. The objectives of the IMPROVE program are:

1. To establish current visibility and aerosol conditions in mandatory U.S. Class I areas;

2. To identify chemical species and emission sources responsible for existing man-made visibility impairment;

3. To document long-term trends for assessing progress towards the national visibility goal contained in the U.S. Clean Air Act; and

4. With the enactment of the Regional Haze Rule (1995), to provide regional haze monitoring data representing all visibility-protected U.S. federal class I areas where practical.

In addition to particulate measurement instrumentation, there are 43 nephelometers in place at various IMPROVE sites across the United States. Nephelometers measure the ability of the ambient atmosphere to scatter and absorb light, which is indicative of haze in the atmosphere. They provide continuous readouts, are relatively inexpensive and can be mounted onto the outside of an existing structure. A nephelometer is to be installed at Egbert.

Further information on IMPROVE is available at a web site operated by Colorado State University, http://vista.cira.colostate.edu/improve/.

There were discussions among the subcommittee of an additional co-location site, possibly at Waterton, Alberta; however, it was decided to ensure that the Egbert site became fully operational and producing data for peer review before any further placements were attempted.

In considering the question of analytical comparability, workshop participants noted that there has been some work on interlaboratory comparisons in the past, as described in Nejedly *et al.* (1998). This paper compares sampling protocols and instrumentation used in four monitoring programs in North America – the Canadian National Air Pollution Surveillance (NAPS) program, the Canadian Air and Precipitation Monitoring Network (CAPMoN), the Canadian Acid Aerosol Measurement Program, CAAMP and finally instrumentation similar to that used in the U.S. - IMPROVE visibility and fine particulate monitoring network, as constructed at the University of Guelph. Three distinct analytical methods often used to analyse the composition of atmospheric aerosols – ion chromatography; photon induced X-ray emission; and X-ray fluorescence – were also compared.

The results of this study indicated that overall trends of air particulate monitoring data obtained by the various sampler/analytical techniques are comparable. However, an examination of individual sampler and analytic outputs revealed variations both in sulphur estimation and in elemental determinations. The variations in sulphur estimation appeared to be an artifact of the various samplers used, while the elemental determinations are in some cases associated with differences in the size fractions determined by the various samplers. Uncertainty associated with single measurements was noted and no basis for declaring any particular data points invalid in the absence of independent corroborative data could be identified.

2.2 Ground-Based Monitoring Networks

Canada and the U.S. both have national and provincial or state ambient monitoring programs and networks. Many differences exist among them, particularly with regard to operating protocol which can make comparisons difficult. In the U.S., monitoring activities must conform to the U.S. Federal Reference Methods promulgated in the Clean Air Act; however, Canadian measurement methodologies are not as rigidly proscribed.

In Canada, the NAPS network, the principal national monitoring program, is cooperatively managed by Environment Canada and the provinces and territories. This network is intended to determine the prevalence and concentrations of ten air pollutants: sulphur dioxide (SO_2); carbon monoxide (CO); nitrogen dioxide (NO_2); ozone (O_3); Particulate Matter 2.5 ($PM_{2.5}$) (speciated); Total Suspended Particulate, $PM_{10;}$ Volatile Organic Compounds (VOCs) (speciated); organic compounds; and elemental carbon (EC). The data from 177 NAPS sites establish concentration trends for these pollutants and support research, including examination of human health effects of air pollution. NAPS data are also used to assess local and mobile (vehicular) source contributions to air pollution in particular urban and regional airsheds.

The CAPMoN network is also managed by Environment Canada in consultation with the provinces and territories. CAPMoN has 24 sites which determine pH (acidity) and organic ions in precipitation, various size fractions of particulate matter (PM, $PM_{2.5}$, PM_{10}), particulate ions, nitric acid (HNO_3), SO_2, O_3, NO, NO_2, NO_y, and peroxy acetyl nitrate (PAN). This network is used to establish spatial and temporal patterns of pollutants related to smog and acid rain. CAPMoN sites are similar to U.S IMPROVE sites, making comparable measurements in non-urban areas, and there is some scrutiny of U.S. measurements to ensure compatibility, particularly for reporting on acid rain.

The new Canadian mercury measuring network, CAMNet (Canadian Atmospheric Mercury Measurement Network), has 12 sites managed by Environment Canada. Measurements of total gaseous mercury and elemental mercury in precipitation are taken in order to determine spatial and temporal variability in these parameters as well as provide data for model development and evaluation. CAMNet also assesses the relative contributions of wet and dry mercury deposition to the total mercury loading from the atmosphere.

Environment Canada's CORE Network Database has six sites which measure greenhouse gases, smog-related gases, aerosols, O_3, VOCs, aldehydes, precipitation, temperature, relative humidity, PM_{10}, and $PM_{2.5}$. This network is designed to provide long-term, high quality observations of atmospheric conditions at locations which represent major atmospheric regimes across Canada. It is also designed to fulfil international commitments for the monitoring of air quality. Further information on this network can be found at (http://www.ec.gc.ca/cleanair-airpur/Air_Pollution_Monitoring_and_Emissions_Inventories/Monitoring/Monitoring_Networks-WS3FF82F98-0_En.htm).

In the United States, monitoring programs are based on the provisions in the Clean Air Act as amended in 1990, which identifies six criteria pollutants: particulate matter; carbon monoxide; sulphur dioxide; nitrogen dioxide; ozone; and lead. Under the Act, the U.S. EPA has the responsibility to set National Ambient Air Quality Standards (NAAQS) for pollutants deemed harmful to human health and other aspects of the environment, and ensure that they are attained. The NAAQS program is also meant to ensure that sources of toxic air pollutants are well controlled. To this end, the U.S. EPA's Ambient Air Monitoring Program was developed and implemented with the support of state and local agencies.

The backbone of the U.S. national ambient air quality monitoring program is the State and Local Air Monitoring Stations (SLAMS) network, whose operation is managed largely by state and local air pollution control agencies. The SLAMS network consists of approximately 4,000 monitoring stations whose spatial distribution and size are largely ascribed by the requirements placed on state and local air pollution control agencies under their State Implementation Plans (SIPs) as approved by the U.S. EPA. There are three major categories of monitoring stations within the network: (1) those that are SLAMS only; (2) those that also have National Air Monitoring Stations (NAMS) status; and (3) those described as Photochemical Assessment Monitoring Stations (PAMS). There are 1,080 stations in the NAMS network, which focus largely on urban and multi-source areas, with emphasis on areas of high population density.

PAMS are required in areas which have serious, severe or extreme ozone non-attainment issues. Each geographic region will have from two to five sites and the total network will exceed 90 sites at the end of the five year phase in period. Equipment at the PAMS sites measures a variety of criteria and non-criteria pollutants, specifically ozone precursors (http://www.epa.gov/oar/oaqps/qa/monprog.html).

Stations in a fourth network, the Special Purpose Monitoring Stations (SPMS) are not permanent, and are usually operated by state, local, tribal and other nongovernmental agencies under specific air programs or to support particular aspects of their SIPs (http://www.epa.gov/oar/oaqps/qa/monprog.html). The attributes of the U.S. IMPROVE network have been discussed earlier in this section of the document.

Over the past few years, the U.S. EPA has reviewed the national air quality monitoring operations and proposed a new national monitoring network design called NCore to improve the collection efficiency and use of the air quality data. This review concluded that the program should emphasize the measurement of fine particulate and ozone and its precursors, while continuing to reduce the measurements of lead, carbon monoxide and coarse particulates (PM_{10}). NCore focuses on multi-pollutant monitoring sites and continuous monitoring networks. NCore will modify the existing NAMS and SLAMS networks into a three level system. Level 1 will be specifically targeted stations for scientific research. Level 2 will consist of the addition of 75 multi-pollutant monitoring stations across the country and will include existing PAMS stations. The data from Level 2 stations would be used to determine trends, health assessments, and air quality models. The construction of pilot Level 2 stations will begin in 2005 and it is expected that all Level 2 stations will be finished by 2007. The Level 3 stations will be used for Air Quality Index (AQI), AIRNow, and compliance purposes. They will be the most numerous and will focus primarily on fine particulate matter and ozone.

In addition, the national monitoring network design also recommended a country-wide assessment of current monitoring stations to identify redundant stations with overlapping network areas. In the year 2000, a national assessment concluded that a substantial number of monitoring stations could be eliminated as they were focused on outdated parameters such as PM_{10} and carbon monoxide. The review also determined that approximately 5-20 percent of monitoring stations for ozone and $PM_{2.5}$ could be eliminated without significantly impacting the quality of the monitoring network. Each state has been given the task of assessing their monitoring stations in order to streamline their network.

Currently, ozone measurements are carried out at 646 SLAMS and 189 NAMS sites; the data from these sites are used for support of SIPs, state and local data, national policy objectives, determination of national trends, measurement of maximum concentrations and some estimation of population exposures. U.S. EPA regional offices and headquarters provide program oversight and data synthesis. As of 2002, there were also approximately 300 SPMS shorter term sites in operation for ozone studies. These are generally used for special studies and state and local oversight, as well as regulatory purposes (http://www.ec.gc.ca/pdb/can_us/qual/2002/section4_e.html).

The PAMS network measures ozone precursors in the most severe ozone non-attainment areas in the U.S., as required by the 1990 Clean Air Act Amendments. PAMS is designed to provide information on the roles of ozone precursors, pollutant transport, and local meteorology in the photochemical process in support of development of ozone control strategies. In 2000, approximately 83 PAMS were in operation in five regions of the United States – the Northeast, the Great Lakes area, Atlanta, Texas (primarily Houston), and California. Further information on this program can be found at http://www.ec.gc.ca/pdb/can_us/qual/2002/section4_e.html.

Canada has a Canada Wide Standard (CWS) for $PM_{2.5}$ of 30 µg/m^3 over a 24 hour averaging time, to be achieved by the year 2010. The CWS are achievable targets to protect the environment and human health as set out by federal, provincial, and territorial Environmental Ministers. These standards alone do not carry any legal weight, and do not replace existing guidelines. The CWS for $PM_{2.5}$ requires daily monitoring which is achieved most efficiently by continuous monitoring equipment. Continuous monitoring also provides near real-time data for use in the AQI and AIRNow. Currently, there is no prescribed measurement method.

Two methods of measurement currently used in Canada are Tapered Element Oscillating Microbalances (TEOM), which is the most common, and Beta Attenuation Monitors (BAM). However, the results from these two instruments are not comparable with either filter based instruments or each other since TEOM readings, which vary with temperature, generally read lower than filter-based measurements, while BAM instruments, while more stable in fluctuating temperature conditions, generally read higher than filter-based measurements. Currently, there is no correlation scheme for the two measurements. The differences in measurements render application of the resultant data under the AQI and the AIRNow more difficult. To overcome these issues a draft Canadian $PM_{2.5}$ reference method and standard operating procedure have been developed and Environment Canada is promoting their inclusion into the CWS Monitoring Protocol document.

2.3 International Efforts

The U.S. and Canada operate and report on the outputs of the Integrated Atmospheric Deposition Network (IADN), which is jointly managed by the U.S. EPA and Environment Canada. The IADN data are used to estimate atmospheric loadings of selected persistent toxic chemicals, including polychlorinated biphenyls (PCBs), lead, cadmium, and polycyclic aromatic hydrocarbons (PAHs), to the Great Lakes basin.

Another joint U.S. and Canada project is the AIRNow network, a web site to provide the public with easy access to national and international air quality information (see http://www.epa.gov/airnow). AIRNow is operated by the U.S. EPA, with collaboration from the NOAA, the U.S. National Park Service (NPS), tribal state and local agencies and Environment Canada. The site offers daily air quality forecasts as well as real-time air quality index readings for particulate matter and ozone for over 300 cities across the United States. The ozone and particulate maps also extend into eastern and western Canada and include data from British Columbia, Alberta, Ontario, Quebec, Newfoundland and Labrador, Prince Edward Island, New Brunswick, and Nova Scotia. There are links to numerous state, local and international air quality web sites. Examples of the daily air quality representations are presented in Figure 3 and Figure 4.

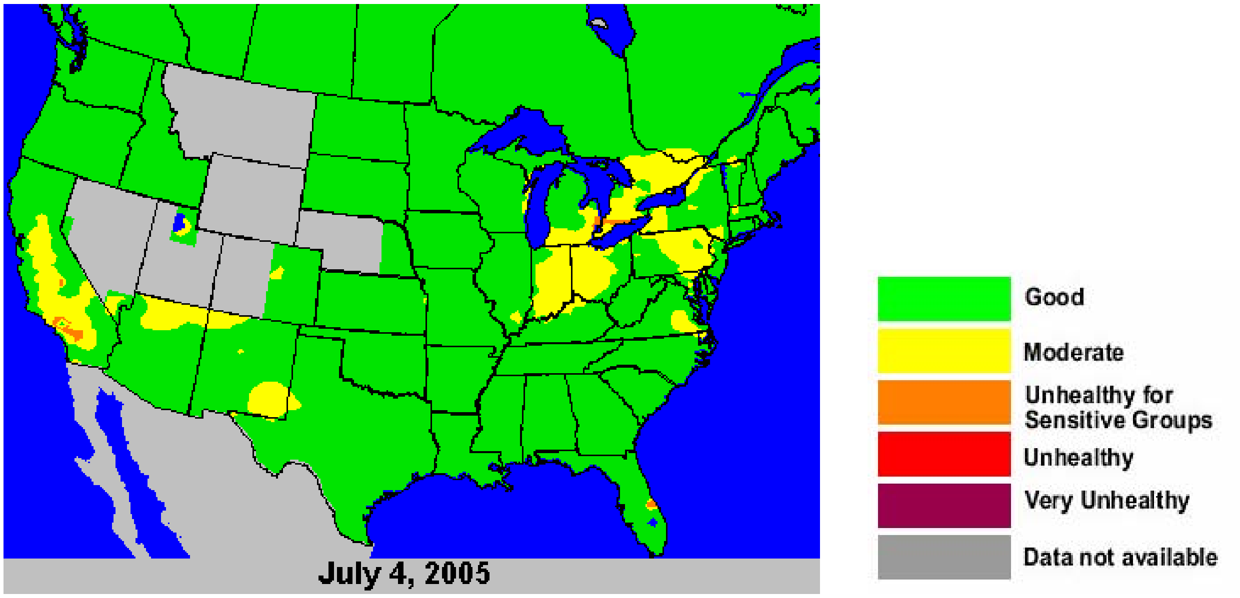


Figure 3: AIRNow Ozone Air Quality Display for the United States (Source: http://airnow.gov/index.cfm?action=airnow.showmap&pollutant=OZONE)

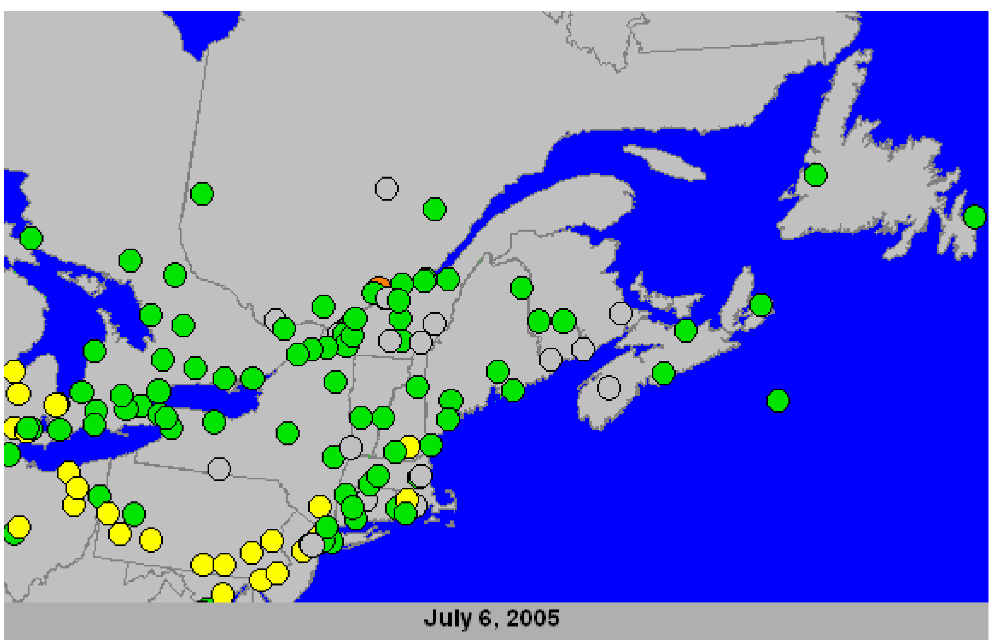


Figure 4: AIRNow $PM_{2.5}$ Air Quality Display for Eastern Canada (Source: http://airnow.gov/index.cfm?action=airnow.showmap)

Another example of transboundary cooperation is the ongoing PM monitoring in Saskatchewan and North Dakota. In 1997, the U.S. government raised concerns that the Boundary Dam Power Plant, a coal fired electrical utility located adjacent to the border in Saskatchewan, may be contributing to transboundary air pollution. Consequently a Transboundary Monitoring Network was established in 1998; electrostatic precipitators were installed on the utility in 1999.

In addition to the monitoring network, forward and backward trajectory analyses were completed to determine the seasonal movement of the air parcel over the utility. This analysis was not related to air quality, but strictly to air movement. The forward trajectory indicated that 50-70 percent of the air mass transport from Saskatchewan terminated in Saskatchewan, Manitoba and southern Ontario. The remaining air terminated in North Dakota, with some movement extending in a south-western direction. The backward trajectory indicated that the majority of the air originated from Alberta and Saskatchewan, with the North Dakota influence peaking during the summer. The study concluded that the air quality is influenced by a combination of local emissions and long range transport.

2.4 Sources

Under current Prevention of Significant Deterioration legislation, the U.S. pays close attention to the lack of visibility in national parks and wildlife areas designated as Class I areas. The Attribution of Haze Phase I project conducted for the Western Regional Air Partnership (WRAP) is designed to determine the source of emissions contributing to the lack of visibility in western Class I areas. WRAP is a voluntary organization made up of western states, tribes and federal agencies that assists states and tribes in the implementation of the Regional Haze Rule by providing them with the required tools and information to prepare State or Tribal Implementation Plans.

Emission inventories, monitoring data and modelling results have been integrated to determine the geographic sources of the emissions, the mass and species distribution of the emissions, and the extent of their impact on visibility. The Attribution of Haze project makes use of data available from the IMPROVE network. The Community Modeling and Analysis System (CMAQ) air quality model developed by the U.S. EPA, in which the Tagged Species Source Apportionment (TSSA) accounted for chemical transformations and deposition, was also used for this study.

Attributions of haze have been completed for over 120 Class I areas and indicate that SO_2 and NO_x are regional pollutants contributing substantially to light extinction. It is clear that emissions from each state impact one or more Class I areas in other states.

There is currently no inter-comparison of VOC measurements between the U.S. and Canada, despite the two countries jointly reporting on VOCs under the Canada-U.S. Air Quality Agreement. Progress reports issued under this Agreement contain summaries from each party on ambient VOC concentrations within 500 km of the border, and there is a focus on emissions of VOCs in transboundary Pollutant Emission Management Areas designated under the Agreement.

Some structured and collaborative comparison of the measurement techniques used for VOC determination by each party could be appropriate. As to the notion of Quality Assurance of analysis of these VOCs, the general ambient air method used in the U.S. is referred to as TO-15. It is the collection of a whole air sample in a canister followed by a GC/MS analysis. An evolving network in the U.S. (known as NATTS - National Air Toxics Trend Sites) uses a "check sample (performance evaluation) program" as part of a quality assurance protocol. This program provides an unknown sample to the laboratories (which could be a Canadian sample) for analyses of its content and a reporting of the results. Results are compiled, allowing for inter-laboratory comparison and evaluation. Information on sources of these VOCs was not considered in the discussion.

The impact of marine emissions was also briefly mentioned at the workshop. Currently, this issue is being investigated in various coastal areas in the U.S. and Canada, with a particular focus on Pacific coast ports. It is also of interest in the Great Lakes basin. Marine emissions should be reduced by the introduction of regulations by the International Maritime Organisation (IMO) on May 19, 2005. These regulations will set a global cap on fuel sulphur content at 4.5% by mass, as well as limits on SO_x and NO_x emissions from ship exhaust, and prohibit the deliberate emission of ozone depleting substances. Various regions will have more stringent requirements; however, emissions from this source sector will likely remain a concern for some time. An opportunity exists for an integrated approach using ground monitoring and remote sensing techniques to determine the strength and dispersal pattern of these emissions

The estimation of total loading of nitrogen is a substantive issue particularly in upland regions and parks, where data on total nitrogen loading in addition to nitrate loading are difficult to obtain. Measurements of dry deposition of this and other contaminants are more problematic than those for wet deposition; an issue that scientists in both governments are reviewing at the moment.

While there has been a considerable effort to determine nitrogen oxide emissions from large point sources and the transportation sector for various other emitted nitrogen species, the lack of consistent source data will be an obstacle to further study. For example, there is considerable uncertainty associated with inventories of ammonia emissions from agricultural operations. In the course of the workshop, ammonia/nitrogen monitoring was also identified as an opportunity for international collaboration.

The workshop discussion reinforced previous comments by the Board of the need for a further focus on the many nitrogen species affecting the ecosystem. Data on several of these species are available, and it is unclear where the focus should be for further work, although NO_y was frequently mentioned as an emerging issue (NO_x is the sum of NO and NO_2 whereas NO_y is the sum of NO, NO_2 and other oxidized nitrogen species such as peroxy acetyl nitrate (PAN), nitric acid, particulate nitrate, nitrous acid and organic nitrates. These other species are often referred to as NO_z: hence $NO_y = NO_x + NO_z$).

The U.S. Regional Planning Organizations (RPOs) are in the process of developing a national ammonia emissions inventory through the RPO National Technical Workgroup. It was suggested that the IAQAB may wish to propose the elements of a nitrogen/ammonia strategy to move forward on these issues, noting that the relationship between ecosystem health and nitrogen enrichment should be addressed in a more comprehensive manner than has been the practice to date.

Ammonia/nitrogen monitoring was also identified at the workshop as an opportunity for collaboration. Work by the U.S. Air Quality Research Subcommittee of the Committee on Environment and Natural Resources was cited as worthy of future consideration.

2.5 Conclusions and Recommendations

The workshop showed that there was a good deal of concern in both Canada and the U.S. regarding the determination of concentrations of particulate matter and ozone. Each country has its own ground-based network for these pollutants; there are also joint efforts to coordinate and promote transboundary monitoring. The Egbert Ontario co-location project is one such effort to determine differences in results of particular measurement systems for PM. Other joint networks include IADN, which determines atmospheric deposition of persistent toxic chemicals, and the U.S. AIRNow network which incorporates data from certain Canadian provinces.

The panel of experts felt that other pollutants such as nitrogen-based species offer an opportunity for further collaboration; NO_y and ammonia emissions from agriculture were mentioned as emerging issues deserving of greater focus.

RECOMMENDATIONS

1. **Continue support of the co-location effort at Egbert as it provides a great opportunity for collaboration. The focus of the current co-location work should be to determine the differences in outputs of the two PM measurement systems and whether a consistent correlation can be developed. This task should be well on its way to completion before committing to a second co-location project.**

2. **Any additional collaboration efforts should be focused on formative areas such as NO_y, ammonia, and other nitrogen compounds.**

3.0 THEME 2: REMOTE SENSING APPLICATIONS IN AIR QUALITY MEASUREMENT AND MANAGEMENT – POSSIBLE APPLICATION IN SUPPORT OF GROUND BASED MONITORING, FORECASTING, AND POLICY DEVELOPMENT

Remote sensing is a term used to describe the process of gathering data and information about the physical world by detecting and measuring radiation, particles and fields associated with objects located beyond the immediate vicinity of the sensing device. Alternatively, it can be defined as a "technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere" (http://rst.gsfc.nasa.gov/Intro/Part2_1.html). This same technology has also been used to look away from the Earth to detect electromagnetic radiation from celestial bodies.

3.1 Satellite Remote Sensing

The focus of the discussion at the workshop was largely on satellite based remote sensing technology and its application to air quality monitoring. There are currently several satellite-mounted sensors possessing attractive features for air quality applications, including Landsat, the Multi-Angle Imaging Spectroradiometer (MISR), the Total Ozone Mapping Spectrometer (TOMS) and the MODerate-resolution Imaging Spectroradiometer (MODIS). This latter system, MODIS, was the focus of the discussions at this workshop.

MODIS instruments are aboard the *Terra* and *Aqua* satellites, which are part of the Earth Observing System (EOS), with *Terra* crossing the equator from north to south in the morning, and *Aqua* passing from south to north in the afternoon. This deployment allows a complete view of the Earth's surface every one to two days. The MODIS project has four associated teams - land, atmosphere, oceans, and calibration. MODIS Atmosphere has a number of currently available products including aerosol, water vapour, cloud, cloud mask and atmospheric profile data. These data are produced in daily, eight-day and monthly outputs.

Figure 5 illustrates how MODIS is able to detect aerosol optical depth (AOD), based on the reflection and scattering of light by aerosols in the atmosphere. Aerosol optical depth (τa) is a measure of the extinction of a direct solar beam during transmittance through the atmosphere (i.e., how much sunlight is prevented from travelling through a column of atmosphere). Most EOS data, including MODIS outputs, are available free of charge through one of the NASA Earth Science Distributed Active Archive Centers (DAACs).

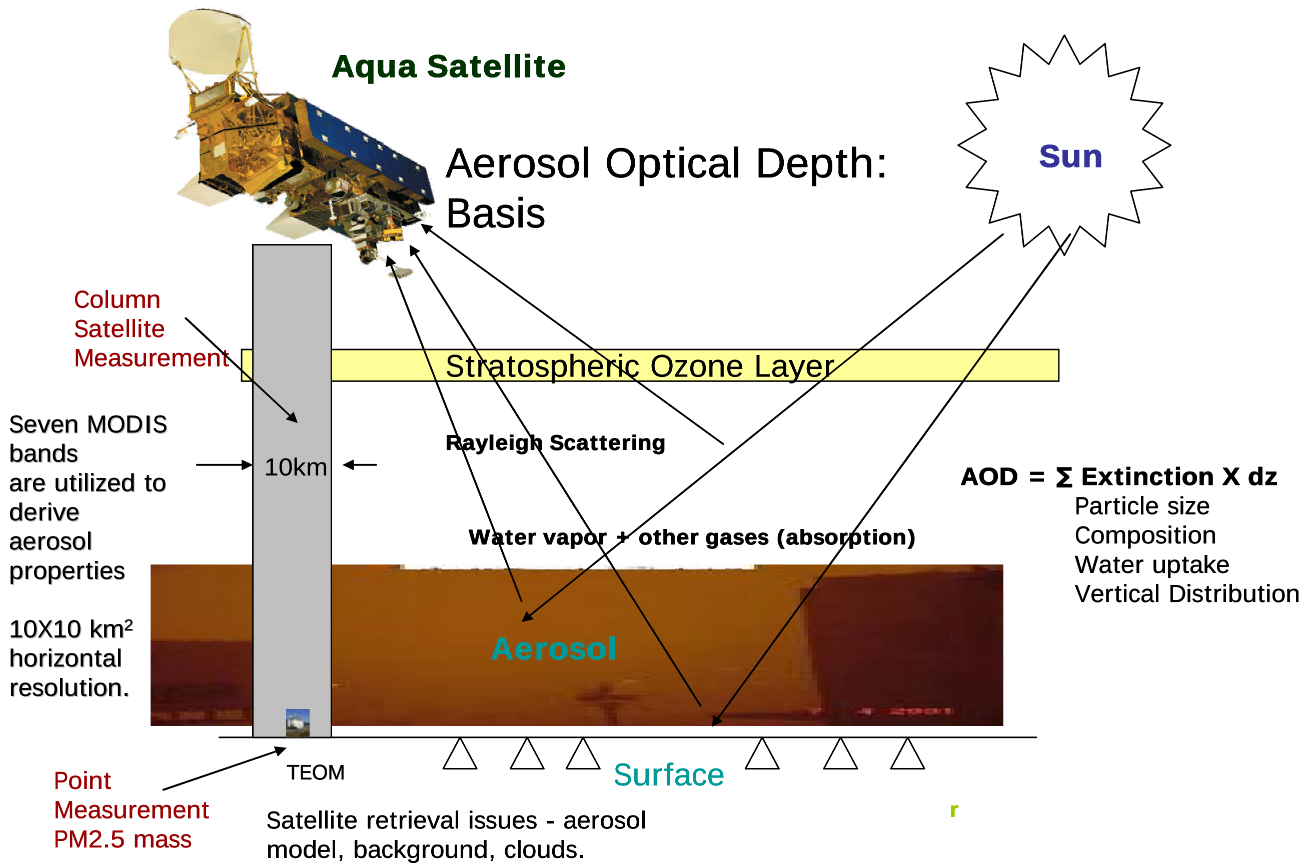


Figure 5: MODIS Aerosol Optical Depth (Source: Szykman presentation)

Plumes from specific events, such as wildfires, dust storms and biomass burning, can be tracked using satellite observations across large areas which may be relatively remote or may cross jurisdictional borders. MODIS data are currently being used in a number of case studies which illustrate the potential application of remotely sensed air quality data and the resultant analysis to the assessment of environmental health implications or decisions on a regional or national basis.

For example, Hutchison (2003) describes how the Texas Commission on Environmental Quality (TCEQ) appealed to the U.S EPA for flexible environmental policy at a national level for large episodic events after identifying, through the use of data generated by remote sensing techniques, three pollution sources external to the state which contribute to non-attainment of standards in areas of Texas. The events considered included continental haze from the industrial mid-U.S., fine sand particles from western Texas or the Sahara Desert and seasonal fire smoke from Central America. How MODIS data allow the tracking of these events is reviewed in the Hutchison paper.

It is possible to detect, speciate and track pollution, especially particulate matter, by remote sensing. Other recent research into the use of remotely sensed data as a tool for monitoring air quality include studies such as Engel-Cox *et al.* (2004), which have found that, although the use of satellite imaging alone may be limited in providing adequate information for air quality monitoring, when used in conjunction with ground-based observations a more effective overall tool is produced. Satellite data add “synoptic information, visualization and validation” (Engel-Cox *et al.* 2004: 2495) to ground-based monitoring. Remote sensing also allows for larger scale and transboundary monitoring, and is useful in providing data in areas where ground monitoring activities are sparse or nonexistent.

IDEA (Infusing satellite Data into Environmental Applications)

One major research initiative in the U.S. is the Infusing satellite Data into Environmental Applications (IDEA) program. IDEA is a partnership among the National Aeronautics and Space Administration (NASA), the U.S. EPA, and the NOAA. It uses remotely sensed data from the MODIS project obtained via NASA and analyses by the U.S. EPA and NOAA in an attempt to integrate work by the different agencies for public benefit. One example discussed at the workshop by Jim Szykman of the U.S. EPA reviewed technical support made available during the development of the Interstate Transport Rule for fine particulate ($PM_{2.5}$) (*69 FR 4566*, 30 January 2004, proposal).

IDEA was used to investigate the application of aerosol optical depth data from MODIS for synoptic information to assist in the validation of year 2002 regional aerosol transport events. IDEA produces vectors and trajectories of pollution, irrespective of the international border, and thus could be used as a measure of transboundary flux in support of the fine particulate annex of the Canada - United States Air Quality Agreement. One of the overall goals of the current IDEA initiative is to “improve accuracy of the predicted next day $PM_{2.5}$ AQI by providing pseudo-synoptic aerosol observations and trajectory forecasts during large aerosol events.” Links were to be developed with AIRNow to enhance the capability of its forecasting.

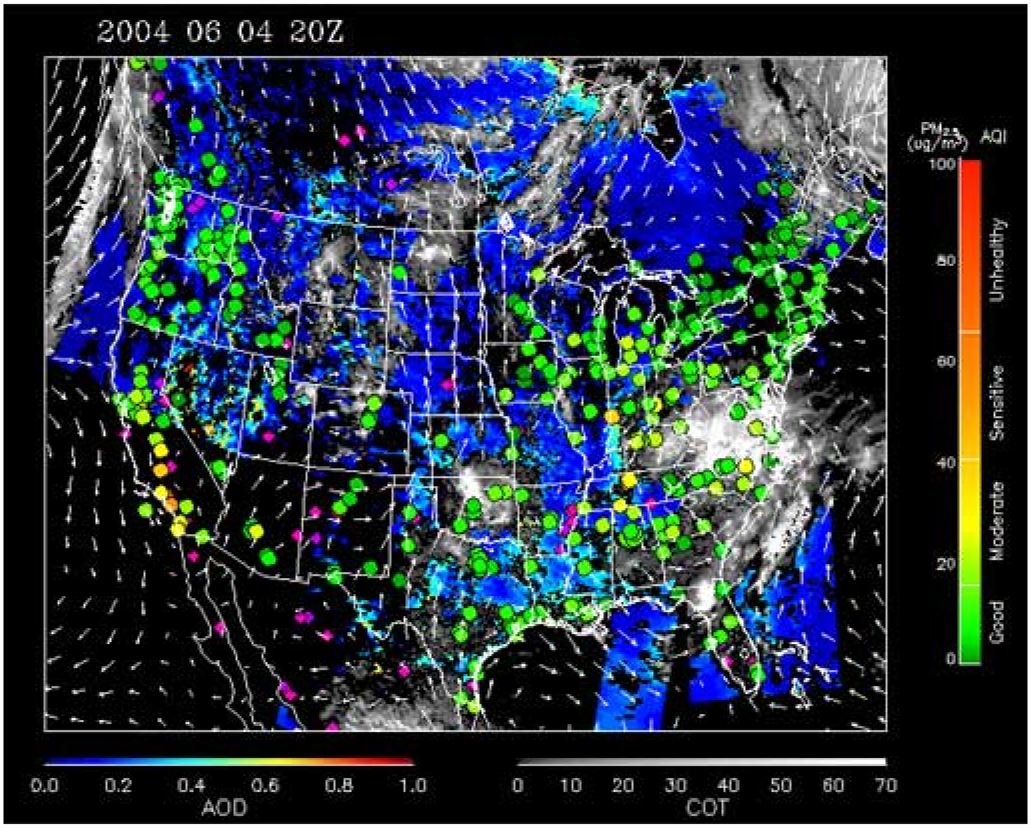


Figure 6: IDEA Three Day Composite History (Source: http://idea.ssec.wisc.edu/)

Figure 6 provides an example of the IDEA output. The data fusion animation plots the most recent three days data [June 4, 2005] of available daily MODIS aerosol optical depth (in color contours), daily MODIS cloud optical thickness (in gray contours), hourly $PM_{2.5}$ concentrations for the in-situ continuous monitors (vertical color bars), NAM 850mb wind field vectors, and half-hourly WF-ABBA fire counts (pink and purple diamonds). This data fusion visualizes the relationship between the MODIS aerosol optical depth, hourly $PM_{2.5}$ mass concentration and the air quality index, providing a pseudo-synoptic view of aerosol events across North America (http://idea.ssec.wisc.edu/).

ICARTT (International Consortium for Atmospheric Research on Transport and Transformation)

The International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) is a multi-lateral effort among the U.S., Canada and Europe using satellites, surface monitors, ships and aircraft to track pollution and its impact on air quality and climate change across the Atlantic Ocean. The three focus areas of this research include: regional air quality; intercontinental transport; and radiation balance in the atmosphere (a parameter related to climate change). ICARTT was formed to take advantage of three parallel research efforts: the NOAA and NASA led Intercontinental Chemical Transport Experiment - North America (INTEX-NA); the New England Air Quality Study - Intercontinental Transport and Chemical Transformation (NEAQS - ITCT); and the

European research under the Intercontinental Transport of Pollution (ITOP) program. The Meteorological Service of Canada participates as well in this undertaking

ICARTT conducted a series of co-ordinated experiments in the summer of 2004 to study the emissions of aerosols and ozone precursors, and their chemical transformations and removal during transport to and over the North Atlantic ocean.

Figure 7 presents the initial monitoring flight paths. At this time, data analysis is taking place and a full preliminary report should be available shortly. However, all of the measurement goals were achieved, and it was found that nocturnal NO_x chemistry appears to play a key role in determining air quality for the following day at downwind locations (Meagher presentation).

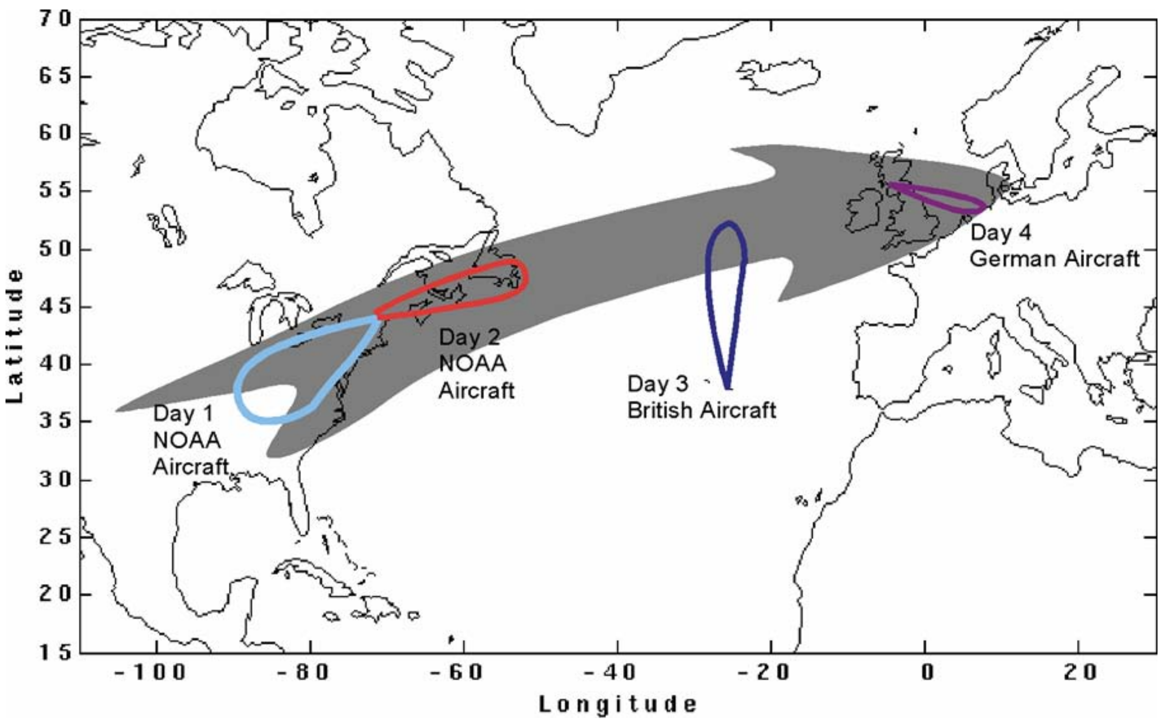


Figure 7: Proposed Flight Paths to Track Intercontinental Aerosol Movement, ICARTT (Source: Meagher presentation)

3.2 LiDAR

Light Detection And Ranging (LiDAR) techniques applied from ground stations and aerial platforms can measure distance, speed, rotation, and chemical composition and concentration of a remote target. A target can be a defined object, such as a vehicle, or a diffuse object such as a smoke plume, a cloud or an acid aerosol. LiDAR hardware sends out short pulses of electromagnetic radiation (laser light in the ultraviolet (UV), visible and infrared range), which are then reflected off the target. In the case of pollution, these reflecting objects can be contaminant particles (even molecules) in the atmosphere. The extent of the reflected light is then measured and recorded.

This technique can accurately determine the location, distance and nature of particles in the atmosphere, enabling the development of a vertical atmospheric profile (http://oea.larc.nasa.gov/PAIS/LaserSensing.html). When used in combination with other remotely sensed data and outputs from ground based monitors, which, for example could define the horizontal or two dimensional extent of a pollution plume, LiDAR can provide a more complete, in some cases, three dimensional, picture of pollutant transport.

The development of LiDAR networks is more advanced in Europe. The European Aerosol Research Lidar NETwork (EARLINET) was established in the year 2000 as a response to the International Panel on Climate Change report calling for improved characterization of aerosols, which presents one of the largest uncertainties in the assessment of climate forcing. From 2000 to 2003, the 20 LiDAR stations in EARLINET conducted routine vertical sounding of atmospheric aerosols over an area from Sweden in the north to Greece in the south and the UK in the west to Belarus in the east. As a result of the project, a database of vertically resolved particle and optical properties was created (Mueller *et al.*, 2004).

The European Commission provided funding for the network through a grant, and it is coordinated by the Max Planck Institute for Meteorology in Hamburg, Germany.

More information is available at http://earlinet.tropos.de:8084/ and http://www.sedoptica.es/revistasanteriores/pdfs/143.pdf. Mueller *et al.* (2004) note that the EARLINET experience may be useful in the development of LiDAR networks in other continents.

There is an existing LiDAR network in the eastern/mid-western United States – REALM (Regional East Atmospheric Lidar Mesonet). Currently, there are 12 participants in this network, including two located in Canada. Table 1 and Figure 8 list participants and their locations.

Table 1: REALM Participants

REALM Regional East Atmospheric Lidar Mesonet Membership
University of Maryland Baltimore County (UMBC) Baltimore MD;
Goddard Space Flight Center (GSFC) Greenbelt MD;
Howard University Beltsville MD;
University of Alabama Huntsville (UAH) Huntsville AL;
Dalhousie University (DAL) Halifax NS;
Meteorological Service of Canada (MSC) Egbert ON;
Hampton University Hampton VA;
University of New Hampshire (UNH) Durham NH;
Pennsylvania State Univ. (PSU) State College PA;
University Wisconsin-Madison (UW) Madison WI;
City College of New York (CCNY) New York City NY; and
Georgia Tech Research Institute (GTRI) Atlanta GA (http://alg.umbc.edu/REALM/RDC/REALM_Daily_Data_Posts/REALM_Participants.pdf)

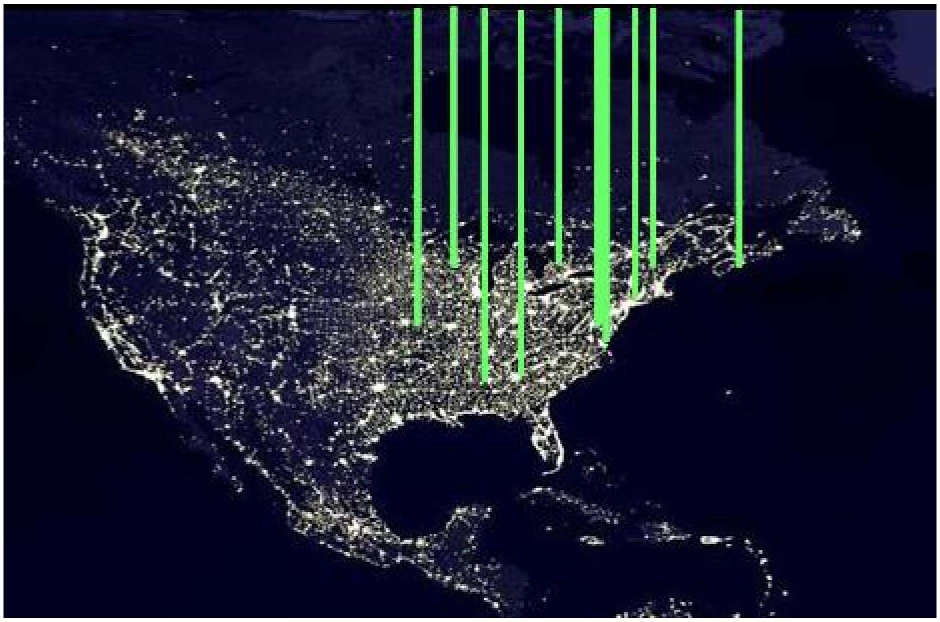


Figure 8: REALM Regional East Atmospheric Lidar Mesonet Membership (Source: Hoff presentation)

The participants in REALM receive no core funding, although there is some support from NOAA sponsored centres. Rather, the network relies on contributions from the user community, and the effort remains a collaboration of LiDAR researchers "interested in making something larger occur than they could individually bring to a project" (Hoff *et al.*, 2003). A larger and more formalized network with multiyear funding could develop a more complete picture of the vertical component of the air mass.

Currently the LiDAR policy applications have not been extensively explored, which could account in part for the relative lack of support. In 2004, Battelle and University of Maryland Baltimore County (UMBC), with support from the U.S. EPA, conducted a small scale pilot project to illustrate how a monitoring network with combined multi-dimensional observations could improve the understanding of air quality transport and assist in accountability through source or source region identification. This project was conducted in conjunction with the U.S EPA's TEOM ground based monitoring network, NASA's MODIS satellite sensor data and UMBC's LiDAR system, for the Baltimore and eastern/mid-western urban regions.

Combining the vertical LiDAR profile with the horizontal satellite images during times when the $PM_{2.5}$ standard was exceeded enabled the team to investigate whether there was variable transport at different levels in the atmosphere. As one example they were able to model the extent of fine particulate pollution above and below the boundary layer (Hoff presentation). Small scale projects similar to this one are crucial to the further development of a case ongoing for funding to support co-ordination and integration of remotely sensed and ground based air quality research.

3.3 Application of Remote Sensing Technology

The University of Maryland Baltimore County hosts the U.S. Air Quality Smog Blog at http://alg.umbc.edu/usaq/. This web site is a daily diary of air quality in the U.S.; data sources include satellite, ground-based LiDAR, and monitoring network data from NASA, NOAA, U.S EPA, AIRNow, MODIS, and local webcams. Staff of the UMBC Atmosphere LiDAR Group update the pages and give interpretations and analysis of the data. There is interest in looking at transboundary issues and including Canadian data in their analysis, as well as a willingness to assist a Canadian university, such as Dalhousie (which has its own LiDAR group), to set up a Smog Blog for all or part of Canada.

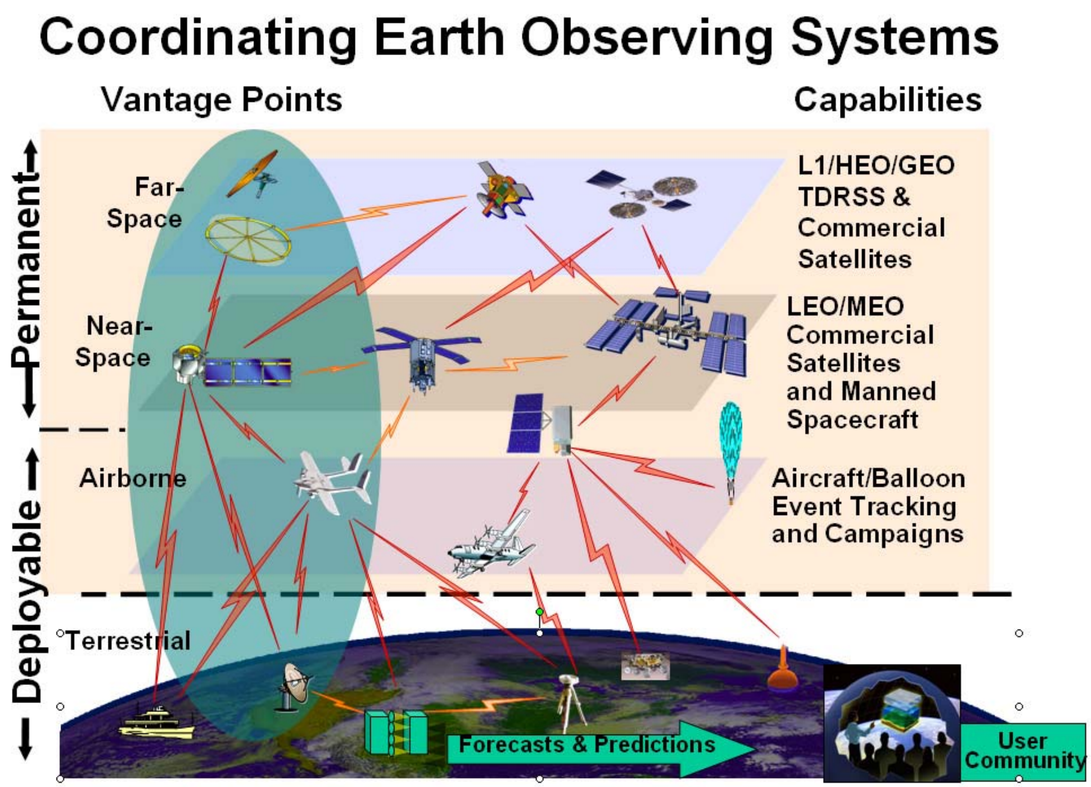


Figure 9: Integrated Earth Observation System Concept (Source: Sheffe presentation)

Air quality monitoring will continue to evolve toward a fully integrated monitoring system. In February 2005, 55 nations adopted the Global Earth Observation System of Systems (GEOSS). GEOSS is a global effort to measure and coordinate comprehensive environmental data from land, air and space and to effectively distribute these data to decision makers. The overall goal is to coordinate earth observation systems around the world to obtain better forecasts and predictions. The U.S. is contributing the Integrated Earth Observation System (IEOS) which will coordinate the U.S. monitoring networks.

A representation of the integrated monitoring network is shown in Figure 9. In this system, the existing ground network will be supplemented with satellite data as well as

LiDAR data and air quality monitoring. The integration of each medium will help eliminate spatial gaps and improve the robustness of the network. The U.S. EPA has indicated that an integrated system could be implemented in the next one to three years.

Based on discussions at the workshop, the IAQAB could advocate further work under GEOSS, for example the extension of LiDAR applications discussed earlier. Currently, in Canada new resources to support GEOSS remain to be identified. Other funding opportunities will have to be identified or created – perhaps through projects that raise the transboundary appeal and attempt to address monitoring gaps. Practical short term projects are needed to demonstrate utility.

Other countries are also experimenting with the use of remotely sensed data in a variety of environmental applications. Currently, the European Space Agency (ESA) has a pilot project using remotely sensed data for environmental policy monitoring. The ESA's TESEO (Treaty Enforcement Services using Earth Observation) program is assisting the Ramsar Convention to estimate the extent of wetlands in Canada, Spain and Senegal. The United Nations Framework Convention on Climate Change has also been involved with TESEO to determine whether satellite imagery and data could be used to continue the development of the Kyoto-mandated national greenhouse inventories. To achieve this, as a first step, research is being conducted on the use of remotely sensed data to monitor forest fires (http://www.esa.int/esaCP/SEMZRU1A6BD_index_0.html).

3.4 Conclusions and Recommendations

The two principal remote sensing technologies reviewed at this workshop were MODIS, a satellite based monitoring technology, and LiDAR, a ground- and air-based technology which can provide a vertical profile of the movement of selected pollutants. At the moment, there is an evident need to effectively incorporate remote sensing with existing monitoring networks to obtain a more comprehensive and accurate picture of air quality is evident. Each monitoring method provides different information on spatial and vertical air quality and the integration of all data would result in a superior descriptor of prevailing and projected air quality. Two programs which integrate remote sensing data and ground-based monitoring, IDEA and ICARTT, have been discussed.

The LiDAR vertical profile network is less well established and less funded, with only 12 monitoring stations in North America although a more extensive network exists in Europe. As is the case with satellite remote sensing, this technology could be incorporated with other monitoring methods to obtain a spatial as well as vertical profile. More small scale integration projects are required to demonstrate the advantages of the technology and obtain the required funding to effectively integrate it with other integrated ground and remote sensing air quality information and research.

RECOMMENDATIONS

1. **The workshop supported practical, short term, and low cost development to the LiDAR network. Once achieved, the focus should shift to integrating the LiDAR network into the existing monitoring networks and air quality forecasts.**

2. **A Canadian Smog Blog similar to the American Smog Blog currently in place at University of Maryland Baltimore County should be established, perhaps at Dalhousie University in Nova Scotia.**

3. **Continuation of work towards more international collaboration on applying remote sensing data to air quality modelling should be actively supported.**

4.0 THEME 3: DEVELOPMENT OF AIR QUALITY INDICES, FORECASTING AND COMMUNICATION PLANS

4.1 Air Quality Index

An Air Quality Index (AQI) provides a generic proxy measurement of air quality at a specific place and time as a means of advising the public in an accessible and straightforward manner. Single numeric values coupled with descriptors such as “good,” “fair” or “poor” and colour codes are intended to provide an easy to understand relative guide to pollution levels, without detail on actual concentrations. The descriptors are usually based on targets or standards set by governments. Recently, specific health warnings or advisories have become associated with the descriptors: one such descriptor is “unhealthy for sensitive groups” which suggests that the elderly and children, especially those with asthma, should consider a reduction in their outdoor activities on days with such warnings. This recent development allows the AQI to be used as a common tool for people to modify their behaviour, usually temporarily, to avoid distress.

4.1.1 Evolution of a National Canadian AQI

In Canada, the first index, the National Index of the Quality of the Air (IQUA), was created in 1976 by a subcommittee of the Federal/Provincial Committee on Air Pollution. It was initially developed for both short term and annual reporting of air pollution measurements. However, due to progress in achieving air quality objectives for other pollutants and the decision to eliminate long term averages from the formulation, by the 1990s the index had become for all intents and purposes a single pollutant index focusing on daily ozone target concentrations, and was used to issue air quality advisories.

In light of new air quality health research, a process to re-examine the effectiveness of the IQUA as an air quality communication tool was begun in 2001. A review of Canadian air quality indices through a stakeholder process followed. The principal findings from this review included the observation that the indices are not explicitly health-based, and advances in health research are not reflected in the index, nor are improvements in monitoring, reporting and forecasting technology. Finally, the value assigned as a measure of air quality remains associated with one pollutant.

On this latter point, while current formulations of the AQI calculate *sub-index* values for between 5 and 7 pollutants (depending on the jurisdiction), only one – the most elevated – is reported as the value of the index at any particular time. There is no consideration of the combined or synergistic effects of multiple pollutants on human health or wellbeing.

For example, on a day where both ozone and $PM_{2.5}$ exceed established thresholds or guidance, only one (the higher) would be reported as the index value. There would be no indication in the index of the high concentration of the other.
As the provinces and municipal governments, particularly in Montreal and Vancouver, issue indices which are not uniform throughout Canada, the need for the national health-based index currently under development is most apparent (http://www.msc-smc.ec.gc.ca/CAQI/faq_e.cfm).

As noted, currently applied indices do not take into consideration the combined effects of pollutants, a situation whose redress will be attempted in development of the new Index. Most of the common air pollutants in Canada are factored into the new index formulation, with the exception of hydrogen sulphide and carbon monoxide. Carbon monoxide is not included because the correlation between carbon monoxide levels currently measured in Canada and distinct health effects is weak compared to those associated with the other criteria air pollutants. Hydrogen sulphide is not included as it is not considered to be a pollutant that is national in scope. The health-based Index is being developed through analysis of the relationship between air quality levels and daily health outcomes. As explained at the workshop, the Index is intended to be used as a daily public information tool, rather than a tool to determine long term trends.

One of the challenges in the evolution of a new Index will be communication of the health message in an appropriate manner, as the public should not be overly deterred from exercising (a common message when air quality is impaired). In order to determine if this challenge is being met, pilot testing of the "Health Advice Scale for Sensitive People" is being considered in New Brunswick and British Columbia in the summer of 2005.

Other challenges include the introduction of a new scale (the new Index will have an open ended 0-10 scale) which may initially prove confusing for the public; this confusion could be compounded in the border region, given the available U.S. AQI. The Pilot test will determine the operability, usability, effectiveness and public acceptance of the new messaging. Phil Blagden, of Environment Canada, encouraged the U.S. Agencies to track these Pilot tests as a first attempt to work together bi-nationally on health messaging, especially in border regions. He noted that the AQI scale does not necessarily have to be identical in the two countries; however, some reference or guidance should be provided, in the manner in which Fahrenheit and Celsius are both used as ambient temperature measurements in border regions.

4.1.2 The AQI Experience in Ontario

The AQI in Ontario, issued by the Ontario Ministry of the Environment (MOE) considers hourly measurements of up to six common air pollutants: carbon monoxide; $PM_{2.5}$; NO_2; O_3; SO_2; and Total Reduced Sulphur compounds (TRS). The Index is divided into five categories, with slightly different health warnings depending on whether the key pollutant is determined to be ozone or particulate matter. The categories are presented in Table 2.

Table 2: MOE Air Quality Index Categories

Category	Colour	Index	Warning
Very Good	Blue	0-15	
Good	Green	16-31	
Moderate	Yellow	32-49	Adverse effects on very sensitive people
Poor	Orange	50-99	Short term adverse effects on human or animal populations. May cause significant damage to vegetation and property
Very Poor	Red	100+	Adverse effects on large proportion of those exposed

The Index is calculated at the end of each hour by converting the concentration of each criteria pollutant into a number from zero upwards on a scale. As noted earlier, *the pollutant with the highest number at any given hour becomes the AQI reading*. The Index is updated throughout the day on the web site www.airqualityontario.com, on the AQI Reporting System phone service (accessed by dialing a free-phone number), and is also reported in local media outlets.

The Ontario Index was first issued in 1988. In 1995, a greater understanding of the health and terrestrial effects of ground level ozone led to a change in the cut-off values for the Index categories. In 2002, Ontario became the first Province to add $PM_{2.5}$ as a criteria pollutant for the AQI. The Index has been designed so that it can be expanded in the future to include additional pollutants as necessary.

Environment Ontario, in conjunction with Environment Canada, also operates a smog advisory program. Since 1993, whenever it is determined that there is a 50 percent chance of a smog day (AQI above 50 due to ground level ozone or $PM_{2.5}$) occurring within the next three days, a Smog Watch is issued. A Smog Advisory is announced when there is a strong likelihood of a smog day within the next 24 hours or when a smog day occurs without warning.

In Ontario, there is a continual outreach and communication program operated by the MOE meant to increase the effectiveness of air quality programs in the province. Much of this work is being conducted at the municipal level, and involves an ongoing dialogue between the MOE and the municipality. Part of this effort is dedicated to gaining a better understanding of municipal implementation issues, particularly among those who have a smog response plan, including discussion of the level of effectiveness of current communication efforts and what the MOE could do to increase effectiveness, as well as the sharing of best practices among municipalities.

While all six regions in Ontario currently have smog response plans, only a quarter of upper-tier municipalities have Municipal Air Quality Action Plans (MAPs). For MAPs to be successful, early notification of poor air quality is necessary. Feedback on the effectiveness of various MAPs should also be tracked continually and the plans updated each year as new information becomes available. MAPs are more successful when they are developed and controlled on the local scale. Examples of some of the elements of MAPs include: Green Fleets policies governing municipal vehicles; energy audits and retrofits; and Green Roofs programs. For example, in Toronto, there is a MAP to make 82 percent of the city fleet hybrid vehicles. Other factors influencing the success of MAPs include:

- Municipal, council and higher level support;
- By-law implementation and community education/advocacy of them;
- Emphasis on potential dollar savings;
- Innovative communications strategies with the media; and
- Smart purchasing decisions.

The MOE is also becoming more involved in municipal consultations, with ongoing contact with municipal project coordinators, and Ministry participation on steering committees and other groups, as requested. A Provincial Working Group has also been established to participate in the national processes.

Recently, the MOE has conducted a media education program, whereby media personnel were invited to technical briefings about Ontario air quality monitoring programs. Media kits have been developed and distributed, and a medical spokesperson is now available to respond to enquiries. The MOE is now cooperating with health units as part of its outreach program to empower health practitioners to give air quality-related health advice, and to strengthen the connection between smog and health.

4.1.3 AQI Programs in the United States

In the United States, a nationally uniform index was developed by the U.S. EPA through co-ordination with the public, health experts and air quality experts to provide the public with general information on air quality. The U.S. AQI is a multi-pollutant algorithm which includes levels of ozone, particulate matter, carbon monoxide, sulphur dioxide and nitrogen dioxide. The Index runs from 0 to 500 where a value of 100 represents the level of health protection associated with the federal health-based Ambient Air Quality Standard for each pollutant (http://www.fraqmd.org/The%20AQI.htm). Table 3 shows the color scheme and related descriptor from the U.S. AQI.

Table 3: U.S. Air Quality Index Categories (Source: http://cfpub.epa.gov/airnow/index.cfm?action=static.aqi)

Category	Colour	Index	Meaning
Good	Green	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	Yellow	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution
Unhealthy for Sensitive Groups	Orange	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected
Unhealthy	Red	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects
Very Unhealthy	Purple	201- 300	Health alert: everyone may experience more serious health effects
Hazardous	Maroon	301-500	Health warnings of emergency conditions. The entire population is more likely to be affected

The descriptors in the table above are general lay summations; specific health-based warnings associated with the individual pollutants ozone and $PM_{2.5}$ are available from the AIRNow web site (www.epa.gov/airnow). This latter program (AIRNow) is described in the 2004 Progress Report under the Canada-U.S. Air Quality Agreement Ozone Annex, as an initiative to compare and calibrate ozone measurements across the border.

4.2 Forecasting Air Quality

4.2.1 Canadian Air Quality Forecasting Activities

The new Canadian national air quality forecasting program has intermediate and ultimate outcomes. On the intermediate timescale, the objective is a program that will enable Canadians to take action to reduce air pollution, give them a better understanding of how to interpret air quality information, and allow them to respond to unhealthy situations by altering behaviour to protect their health. Ultimate or longer range outcomes of the forecast program are anticipated to be improvements in air quality and a reduction in the effects of air pollution, including the extent to which the population experiences distress and seeks medical treatment.

Clean Air is a major priority of the Government of Canada, and the national air quality forecast program supports this priority by:

- Providing vulnerable individuals with daily forecasts so they might reduce their health risks;
- Supporting the reduction of emissions by individuals, organisations and communities;
- Supporting provincial and municipal air quality regulations and programs; and
- Addressing the public 'right to know' impending air quality conditions.

Forecasting challenges vary across the country with the prevailing air pollution issues and sources. For example, forest fires are prevalent in western Canada and Quebec, and smog conditions are a particular concern in southern Ontario. Environment Canada is developing an air quality model to incorporate $PM_{2.5}$ emissions from forest fires into air quality forecasts. The CHRONOS (Canadian Hemispheric and Regional Ozone and NO_x System) model is currently operating for PM and ozone across the North American domain with 48 hour forecast maps. Ultimately, the CHRONOS model will accurately integrate real-time forest fire data from satellite imagery. The program also requires the creation of a database of emission rates based on forest types and vegetation cover in Canada and the United States. Cooperation between Canada and the U.S. has been identified as an issue since CHRONOS needs real-time access to satellite imagery using MODIS or the Advanced Very High Resolution Radiometer (AVHRR). It also requires collaboration to process the data in real time (http://www.msc-smc.ec.gc.ca/aq_smog/chronos_e.cfm). At this time CHRONOS is considered to be still under development and should be used as a guidance tool only.

Currently, 75 percent of Canadians live in an area where there is a daily air quality forecast for at least part of the year. However, many regions have a forecast only in the summer months and for a limited number of pollutants. As part of national standardisation, a forecast will become available year-round across Canada. There will be an evolution from traditional weather forecasting to an 'environmental forecast,' which will include air quality information. Continuing improvements in research and modelling will be used to upgrade the forecast. The feasibility of including NO_2 and SO_2 in addition to PM and ozone currently considered in the program is under examination.

Outreach and public education are integral to the success of this forecast program. An interactive web site is to be created to educate and to allow Canadians to use the forecast as a decision making tool. The full implementation of the new health-based AQI is expected in 2007, which will be linked to this forecasting effort; continual assessment of performance will provide feedback for the next steps in development.

Partnerships with U.S. agencies, as well as provincial and municipal groups, are seen as critical for the success of the Canadian national forecast program. The Meteorological Service of Canada (MSC) has formed an Operational Air Quality Working Group with NOAA, which includes cross-border training programs. Currently, the MSC is looking to forge closer relationships with the U.S. EPA. The AIRNow program is a collaboration involving data exchange; however, there is movement towards a more formal collaborative relationship, with initial discussion to take place prior to mid-2005.

Four themes which could form the focus of the continued development of this program:

- Standardisation;
- Research and Development/Modelling;
- Outreach; and
- Performance Measurement.

4.2.2 AQ Forecasting in the United States

The U.S. National Weather Service (NWS) is also working towards a national air quality forecasting capability. The vision of this forecast is very similar to that of the Canadian program; to provide ozone, PM and other pollutant forecasts with enough accuracy and advance notice to allow the public and other parties to take action to prevent or reduce adverse effects. The NWS does not maintain a focus on health effects and benefits per se, as this is not part of their mandate. The NWS strategy for this aspect of the forecasting program is to work in collaboration with the U.S. EPA, state and local agencies, as well as the private sector, to develop an "end-to-end air quality forecast capability for the nation."

Currently, the NWS has a one day *ozone* forecasting tool for the north eastern U.S., available at the interactive web site www.weather.gov/aq. Released in 2004 with the objective of extending it to the whole of the U.S. by 2009, to date it has been well received by forecasters, scientists and the general public alike. During testing in the summer of 2004, greater than the required 90 percent accuracy level was consistently achieved, and there were only seven days when the forecast was below 95 percent accurate. The next step for this forecast will be the inclusion of *particulate matter*; within 10 years, it is anticipated that the range will be extended to 8-72 hour national forecasts for a range of pollutants.

The NWS has been collaborating with Canada in this program through technical coordination meetings, working groups on specific topics, cross training of forecasters and developmental focus groups (Davidson presentation).

4.2.2.1 Air Quality Information and Forecasting in U.S. National Parks

The U.S. National Parks Service (NPS) is providing air quality information in selected National Parks, on its web site (www2.nature.nps.gov/air). The NPS is providing air quality information due to several factors:

- Many Parks are on occasion exceeding the U.S EPA 8hr-ozone standard;
- Individuals often have high exertion levels when visiting Parks – there is a need to protect sensitive populations; and
- There is a need to protect staff from long-term exposure.

However, information made available is not standardised across the Parks, but varies with the individual park. Online, some Parks have a visibility camera displayed on a web site which also offers weather and air quality conditions – largely ozone concentrations. The associated health implications of air pollution are also often described as well, as are recent trend data for weather and air quality. Some individual Parks report only ozone, some only particulate matter, and some report both pollutants.

An example of one of these reports can be found for the Great Smoky Mountains National Park at http://www2.nature.nps.gov/air/WebCams/parks/grsmpkcam/grsmpkcam.cfm.
These pages also contain a link to the AIRNow web site. On AIRNow, there are specific maps available that also illustrate the air quality in the National Parks. More detailed ozone maps within some parks are also available in the summer months.

Among the Parks, there is a lack of consistency with air quality messaging. Ozone advisories are issued to visitors to six National Parks. In three parks – Acadia, Great Smoky Mountains, and Mammoth Cave – ozone advisory signs similar to that in Figure 10 are widely displayed inside the Park, combined with announcements. Along the highway to Great Smoky Mountains, there are also electronic signs advising of prevailing concentrations of ozone and particulate matter. These signs inform the public which particular locales may be unhealthy, such as those above a certain elevation, and suggest that visitors stop in at the visitor centre for further information. The other three parks which issue warnings do so on a more limited scale, largely to inform park staff of conditions. These are Sequoia-Kings Canyon, Shenandoah, and Joshua Tree National Parks. In 2004, out of these six National Parks, plus the Pinnades, there were a total of 60 ozone health advisories issued.

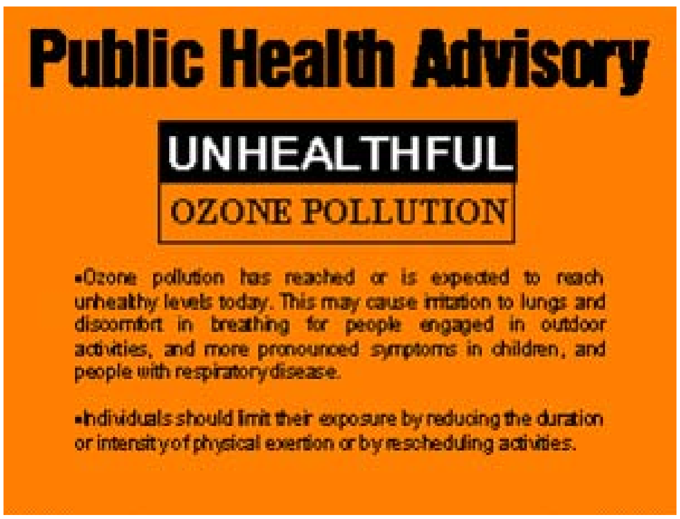


Figure 10: Ozone Advisory Sign used at Acadia National Park (Source: Ray presentation)

The issue of actual or potential losses in revenue to the Parks due to a drop in visitation resulting from advice on poor air quality remains a concern, but as yet the advisories do not seem to have had a detrimental effect on revenues.

4.3 Conclusions and Recommendations

The issue of "creating a border region approach" (an objective from the first KCAC/PSD workshop) is perhaps most pertinent with respect to the evolution of AQIs, particularly in the border areas.

In border regions, communities may have relatively simple means of access to the AQI from both jurisdictions. However, as noted, each of the two systems has a distinct health effects scale and associated descriptors. The current lack of consistency between the Canadian and American AQIs could be a source of confusion to residents living along the boundary, which in turn could undermine the authority of the forecast. While the associated air quality numerical standards have become more closely aligned in recent years, a complete harmonisation in the near future is unlikely. As noted above, other means should be developed to address this issue.

As both Canadians and Americans demand air quality forecasts, the trend towards environmental forecasting is growing and partnerships between the two countries are gaining importance. Data sharing as well as coordinated delivery of the forecasts are essential for provision of timely and consistent advice.

RECOMMENDATIONS

1. **In order to reduce the potential confusion of border area residents in the interpretation of the AQIs for each country, the IJC should continue to encourage international coordination of AQI development and application. If complete coordination proves to be impractical, a frame of reference should be provided so that residents are able to interpret AQI information from the other jurisdiction.**

2. **An air quality information distribution system for Canadian National Parks similar to the system in place at certain American National Parks should be implemented.**

5.0 FINDINGS AND RECOMMENDATIONS FOR FUTURE WORK

The last session of the workshop was devoted to the development of preliminary findings and recommendations, which are presented below. Note that these have been developed by the workshop participants rather than the members of the International Air Quality Advisory Board.

1. **The International Joint Commission should remain involved with the collaborative efforts in air quality research between the U.S. and Canada. However, a niche for the IJC needs to be carefully defined so that the focus remains on practical on the ground cooperation and interchange, contributing to possible positive policy discussions.**

2. **In determining its niche, the IJC should identify its role among other entities involved in transboundary air quality including those associated with the U.S.-Canada Air Quality Agreement, NARSTO, and the Commission for Environmental Co-operation, particularly their Environmental Monitoring and Assessment and Sound Management of Chemicals Activities, the UN Economic Commission for Europe and its related protocols, and the U.S.-Canada Border Air Quality Strategy. It may prove difficult for the IJC to become involved with the entire gamut of currently established and ongoing activities so the Board and the Commission may need to identify formative areas that present the best opportunity for constructive engagement.**

3. **The workshop panel advocated continuation of a liaison role among the various groups and different levels of government, to encourage further work specifically in support of further transboundary and bilateral scientific objectives. A recommended first objective for the IAQAB is to continue to identify formative areas for collaboration. Some recommendations for such areas are listed below. The IAQAB should:**

   i) **Review current monitoring and modelling of ammonium and total nitrogen (including distinctions between NO_x, NO_y, etc.). Suggest and support collaborative activities in these areas to further increase the understanding of nitrogen cycling, including ecosystem health and nitrogen enrichment.**

   ii) **Recommend and support increased collaboration between personnel operating ambient monitoring networks, both inter- and intra- country, and suggest a structure or series of activities to facilitate this. Continued encouragement of specialist groups such as the Monitoring Subcommittee to support the further evolution of specific science objectives is seen as appropriate.**

iii) Review current opportunities within satellite remote sensing technology as a scientific and policy tool in the air quality field. Identify smaller-scale shorter-term initial projects, such as further event analysis, to demonstrate the potential of linking this technology and ground based monitoring and modelling efforts. Particular elements could include:

a) A focus on developing a LiDAR network similar to that found in Europe; and

b) Facilitation of liaisons to develop a Canadian Smog Blog.

iv) Advocate further consistency in messaging of air quality information and its health implications to the public, especially in border regions, given that the illustrative information associated with each index differs between the countries. Development of a comparative guide to the two systems for use in the transboundary region should be advocated.

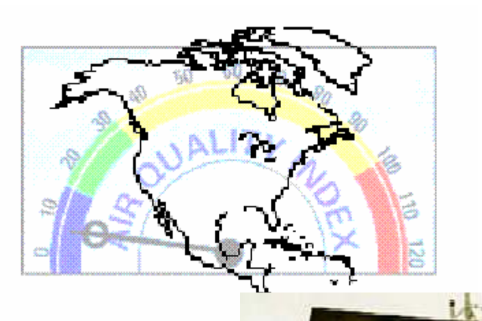
4. Further examine ecosystem health impacts on a bilateral basis, for example extend the forest sensitivity mapping project in the New England states and Atlantic Provinces to other areas along the boundary.

5. Encourage subsequent meetings/events with broad participation of local, state/provincial, and federal personnel. These events should continue to support participation by policy makers to initiate and maintain the dialogue among these groups.

Appendix A Workshop Brochure

March 7, 2005
Beyond Keeping Clean Areas Clean and Prevention of Significant Deterioration:
Exploring Collaborative Opportunities in Air Quality Monitoring, Modelling and Communication

David Skaggs Research Center
National Oceanic and Atmospheric Administration Building
325 Broadway, Boulder, Colorado



March 22 and 23, 2005

International Air Quality Advisory Board,
International Joint Commission
Environment Canada
National Oceanic and Atmospheric Administration

Tuesday March 22, 2005

Facilitator: Jill Engel-Cox, Battelle Memorial Institute

8:30 am	**1.0**	**Welcome and Introductions** - Ann McMillan, IAQAB/Jill Engel-Cox, Battelle Memorial Institute	
8:50 am	**2.0**	**Update and Progress since 1st KCAC/PSD Workshop, Feb 23-24, 2004** ***Session Chair: Kathy Tonnessen, US National Park Service***	
8:55 am	2.1		Summary of Main Findings from 1st KCAC/PSD - Ann McMillan, Environment Canada
9:15 am	2.2		Development of Canada's National Guidance Document on Continuous Improvement and Keeping Clean Areas Clean - Peggy Farnsworth, Environment Canada
9:40 am	2.3		Update on Co-operative Initiatives: Co-location of Fine Particulate Monitors - Marc Pitchford, NOAA
10:05 am	Question and Answers		
10:15 am	**BREAK**		
10:30 am	**3.0**	**Use of Remote Sensing Techniques in Monitoring and Modelling of Continental and Global Transport of Fine Particulates and Ozone*Session Chair: Rich Poirot, Vermont Agency of Natural Resources***	
10:35 am	3.1		International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) - an Overview - Jim Meagher, NOAA
11:00 am	3.2		Infusing satellite Data into Environmental Applications (IDEA) program - Jim Szykman, US EPA
11:25 am	3.3		The Use of Remote Sensing for Air Quality Forecasting - Ray Hoff, University of Maryland, Baltimore Co
11:50 am	3.4		Event-based Modelling - Louis-Philipe Crevier/Keith Puckett, Environment Canada
12:15 pm	Questions and Answers		
12:25 pm	**LUNCH**		
1:30 pm	**4.0**	**Review of U.S. and Canadian Fine PM Networks and Transboundary Applications** ***Session Chair: Marc Pitchford, NOAA***	
1:35 pm	4.1		Update on Evolution of National Fine PM Monitoring Networks - Tom Dann, Environment Canada - Rich Scheffe, US EPA
2:25 pm	4.2 4.2.1		Scientific Approaches Source Attribution Modelling under the US IMPROVE Program - Tom Moore, Western Regional Air Partnership

2:50 pm **BREAK**

3:05 pm 4.2.2 IMPROVE and the Regional Haze Rule – Further Developments
- Bill Malm, US National Park Service

3:30 pm 4.2.3 Transboundary PM Transport in Mid-Continent North America
- Bill Hume, Environment Canada

3:55 pm Questions and Answers/Closing

4:15 pm **END OF DAY ONE**

Wednesday March 23, 2005

9:00 am **5.0** **Development and Communication of Information on Air Quality**
Session Chair: Randy Piercey, Dept. of Environment and Local Government, New Brunswick

9:05 am 5.1 National Approaches to AQ Forecasting
5.1.1 NOAA-EPA National Air Quality Forecast Capability: Initial Implementation, Progress and Plans
- Paula Davidson, NOAA

9:30 am 5.1.2 Canada's National Air Quality Forecast Program
- Mike Howe, Environment Canada

10:00 am 5.2 Health-based National Air Quality Indices
- Phil Blagden, Environment Canada

10:30 am **BREAK**

10:45 am 5.3 Ontario's Experiences with Air Quality Indices, Outreach and Communication
- Ellen Vansteenburgh/Dave Yap, Ontario MOE

11:25 am 5.4 Ozone Health Advisory and Webcams
- John Ray, US National Park Service

11:45 am Questions and Answers

12 noon **LUNCH**

1:15 pm **6.0** **Moving Forward – Panel Session – Jill Engel-Cox**
- Kathy Tonnessen, Rich Poirot, Marc Pitchford, Randy Piercey, Ann McMillan, Tom Dann and Keith Puckett

Please refer to overleaf for goals of Panel Discussion

3:15 pm **7.0** **Closing Remarks**

Goals – Panel Discussion

The panel discussion will be an opportunity for the facilitator and the session chairs to summarise the major findings of the sessions, to identify practical opportunities for near term transboundary collaboration in monitoring and modeling, particularly the integration of satellite data into these programs. Techniques for improved air quality forecasting and communication strategies between agencies and the public will also be reconsidered and reinforced.

Environnement Canada Environment Canada

The First Clean Areas/Prevention of Significant Deterioration Workshop held in Vancouver in February 2004 reviewed the Canadian and United States approaches to these two goals in detail, along with many of the associated scientific issues. This second event will explore the status of several of the recommendations from the first workshop, with emphasis on the modelling of large scale fine particulate and ozone events and the status of fine particulate monitoring programs and co-location opportunities. The use of remote sensing as a tool in air quality applications will be explored. In addition, recent developments in air quality indices and forecasting, and their role in effectively communicating information on air quality to the public, will be examined.

Contact:

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Appendix B

Participants List

Workshop Participants
Clean Areas/Prevention of Deterioration
Second Workshop Boulder, Colorado, March 22 - 23, 2005

Blagden, Philip Senior Science Policy Advisor Environment Canada Gatineau, QC	Blaney, Jack P. Commissioner Vancouver, BC
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Mignacca, Domenic	Moore, Tom

Air Pollution Prevention Directorate Environment Canada Gatineau, PQ	Colorado State University Fort Collins, CO
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Polkowsky, Bruce Policy Planning and Permit Review Branch Air Resources Division Denver, CO	Puckett, Keith Environment Canada Downsview, ON
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Szykman, Jim Environmental Sciences Division Hampton, VA	Tonnessen, Kathy Ann University of Montana Missoula, MT
VanSteenburgh, Ellen Coordinator, Special Projects & Intellectual Property - Strategic Projects and Planning Etobicoke, ON	Welch, David Parks Canada Gatineau, PQ
Yap, Dave Ontario Ministry of the Environment Etobicoke, ON	