Environment and Climate Change Canada
Environnement et Changement climatique Canada

The Toronto 2015 Pan and Parapan American Games Experience

An Environment and Climate Change Canada Perspective

Canada

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The Toronto 2015 Pan and Parapan American Games Experience

An Environment and Climate Change Canada Perspective

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In July and August 2015, Canada hosted the Pan American and Parapan American Games in Toronto, Ontario. The Government of Canada played a critical role during these Games, which included Environment and Climate Change Canada (ECCC) doing its part to make the Games safe and an overall success. It provided our department an opportunity to integrate, test and showcase to the world our innovations, technological capabilities, ability to deliver, flexibility in working together with partners to better integrate decision making, and our concern for public safety and the environment. Through this project report, we are pleased to present ECCC's achievements and lessons learned stemming from our engagement in the Games. They have resulted in significant insight in improving weather and environmental forecasting to protect the health of Canadians, improve their safety and enhance their economic competitiveness.

ECCC's Meteorological Service of Canada (MSC) is one of Canada's oldest federal institutions. It has been delivering weather information to Canadians since 1871 and is responsible for activities related to weather forecasts and warnings, the ice service, climate and air quality. Throughout its history, the organization has been a leader in scientific and technological innovation, and strives to continuously improve its operational systems in the area of weather monitoring and forecasting. The 2015 Games Project highlighted a number of key initiatives that will significantly improve our understanding of important meteorological phenomena in urban areas. It also highlighted our staff's ability to maintain the high quality of services that Canadians expect and were clearly provided leading up to and during the Games.


KAREN DODDS

The core public service of the MSC remains our weather forecasting. During any given year, the MSC produces thousands of public weather forecasts and alerts as well as providing ice, climate and water information to our stakeholders. During the Games alone, we issued 463 venue-specific public and marine forecasts, 37 venue-specific weather warnings, watches and advisories, and 69 Air Quality Health Index (AQHI) forecasts.


DAVID GRIMES

The Science and Technology Branch (S&T) of ECCC is mandated to perform research and development activities, and along with the Department as a whole is recognized as a leader in the production of environmental scientific knowledge both in Canada and internationally. Working with our partners, we undertake science that is timely and relevant to Canadians. S&T is a key Canadian focal point for the advancement of atmospheric science, research that contributes to improve Canada's air quality, respond to climate change and increase the accuracy of weather forecasts. Atmospheric research also provides the scientific basis for many services to Canadians, including the AQHI, the UV Index, and increasingly accurate forecasts of severe weather. For the 2015 Toronto Games, we are very proud of the accomplishments of staff, whose exemplary efforts have resulted in improved measurement techniques and high-resolution numerical weather prediction systems, enhanced AQHI forecasts, legacy datasets that will help inform policy strategies related to ambient air quality standards in urban environments, and scientific innovations that will likely be integrated in the next generation of operational forecasting systems currently under development.

The success we have enjoyed during the Games is the direct result of the dedication of thousands of employees in ECCC and other federal partner organizations, and colleagues from provincial, regional and municipal governments. Without their hard work and enthusiasm, the significant accomplishments that were achieved would not have been possible. We salute them for their devotion and our successes, and thank them for their continued professionalism and commitment to uphold the values of a strong federal public service.

We are pleased about the outlook of ECCC's future because we know that the people we have, the research we do and the services we provide make us an example of excellence in government. 2016 marks the 145th anniversary of our meteorological services. We believe that we can set the course for another 145 years and beyond of providing core, leading-edge government service to Canadians and helping Canada remain one of the best countries in the world in which to live.

We invite you to review our many accomplishments over the last five years by reading through the Pan and Parapan American Games project report.

DAVID GRIMES
Assistant Deputy Minister
Meteorological Service of Canada

KAREN DODDS
Assistant Deputy Minister
Science and Technology Branch

FOREWORD FROM THE PROJECT'S SENIOR EXECUTIVE

This 2015 Pan and Parapan American Games project report summarizes the activities that were carried out by Environment and Climate Change Canada (ECCC) to fulfill our mandate to help protect the health and safety of Canadians and our international guests during the Games.

ECCC's Meteorological Service of Canada (MSC) is an essential service of the federal government. It contributes to the health, safety and economic prosperity of Canadians by providing accurate and accessible information on weather, climate, water and ice conditions across Canada. The MSC helps safeguard Canadians from environmental emergencies (natural or human-made), and provides support to other federal departments with security mandates, such as the Department of National Defence, Public Safety Canada and the Royal Canadian Mounted Police.

The MSC has been serving Canadians since 1871, when the national weather service was created to provide warnings to mariners on the Great Lakes and the St. Lawrence River. Today, the MSC is part of a nation-wide service that provides public and marine weather forecasts and alerts while operating everything from radar and lightning detection networks to ocean buoys and automated land weather stations. For the Games, ECCC strategically designed and installed a high-resolution multi-platform network of state-of-the-art, automated atmospheric monitoring instruments across the Games footprint in southern Ontario's Greater Golden Horseshoe Area. Data from this network was used by our forecasters to produce venue-specific forecasts and alerts. Scientists are also using this data to evaluate both atmospheric research and technological innovations to continuously improve upon severe weather detection and early warning notification. In this way, the work done by the Project Team benefited ECCC, and ultimately every Canadian, in a variety of different ways.

MICHEL JEAN

Weather products are among the most frequently used of the federal government services, which was also the case during the Games. Our forecasts and alerts were used by the Toronto 2015 (TO2015) Games organizers, volunteers, athletes and security teams in support of safety and security. There is a long history of ECCC providing quality service to Canadians, and I am proud to say that this tradition continued in full force pre-, during and post-Games.

MICHEL JEAN
Director General
Canadian Centre for Meteorological and Environmental Prediction


TORONTO 2015
TORONTO 2015
JOUONS UNIS!
UNITED WE PLAY!
¡UNIDOS JUGAMOS!
TORONTO 2015

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EXECUTIVE SUMMARY

This report is a description of the Environment and Climate Change Canada (ECCC, formerly Environment Canada) Project Team's experiences in their support to the Toronto 2015 Pan and Parapan American Games (hereafter, the Games). Reflecting on these experiences allows us to synthesize lessons for the improvement of Canadian meteorological services in ways that can benefit future projects and service delivery in general. ECCC's Meteorological Service of Canada (MSC) is already proud of its accomplishments and world-class services. The Games allowed the MSC to harness those world-class services, sharpen the focus on a relatively small region of Canada, and increase the temporal and spatial resolution of observations in that small region to augment meteorological services provided for the Games.

The XVII Pan American Games and the V Parapan American Games were held in Toronto, Canada, from July 10–26, 2015, and from August 7–15, 2015, respectively. Canada welcomed the 40 other countries/nations of the Americas to Toronto and the municipalities of the Greater Golden Horseshoe Area in Ontario where the summer sports events of the 2015 Pan and Parapan American Games were hosted.

Approximately 11,000 athletes, athlete support personnel and technical officials participated in the Games. ECCC's mission and mandate for the Games were to provide essential services for enhanced weather monitoring and forecasting and for local-level preparedness activities to enhance public safety and decision making.

ECCC derives its mandate from the *Department of the Environment Act*, which requires implementing environmental legislation, policies and programs to protect, maintain and enhance the quality of the natural environment. It also requires that Canadians are provided with the information they need to make informed decisions to protect their health, safety and security, and economic prosperity in the face of changing weather and environmental conditions.

Flowing naturally from the Department's mandate, during the creation of the Treasury Board Submission, ECCC had to capture its mission and contributions to the Games. This mission was to provide essential services for enhanced weather monitoring, alerting, and forecasting, for local-level preparedness activities, and to support environmental assessments of projects relating to the Games. The Treasury Board granted ECCC funding starting in 2012 to provide the essential services specific to the Games that were outside the normal scope of duties for the Department. These funds were spent primarily by the MSC.

Once the mission and objectives were well understood, ECCC began developing a Project plan in 2012. It was important to clarify where ECCC fit within the sporting world of the Pan and Parapan American Games Organizing Committee and within the Essential Federal Services (EFS) picture in order to properly support the operations of the Games and the federal services related to safety and security at the Games.

From the Project's inception through to its closure, close to 450 people within ECCC made contributions to ensure the success of the delivery of services. During the earliest days, a small expert team representing monitoring, prediction and services, science and information technology was formed to craft, negotiate and document ECCC's contributions to the Games in the Treasury Board Submission. Internally, the design for the Project structure started to take shape once the scope of the Project was approved with funding authorized for spending by the Treasury Board Secretariat. A Project Lead was identified within ECCC, and a Project Office Manager and Project Assurer chosen to lead and coordinate the work prior to, during and after the Games.

A Steering Committee, Project Board and Working Groups were created in support of ECCC's project for the Games. There was a great deal of leadership provided across branches within the Department, where expertise was leveraged to provide strong advice, guidance, support and direction to the Project Office.

The Project Team began with the necessities. There had to be a design for the new atmospheric monitoring network, known as the Mesonet, to cover all venue locations and transportation routes between them. Early on, with only a few partners engaged, the Project Team anticipated additional needs for the Project and built in some flexibilities while assessing and mitigating risks along the way. For example, although ECCC formally did not provide sport-specific forecasts or alerts, the briefing teams understood the value of weather briefings and the importance of tailoring observational data and forecasts to enable sport organizations to make sport-specific decisions.

Additionally, a new meteorological workstation was designed for use during the Games such that it could be easily replicated and re-used for future events. Data capture and archival techniques were modified to include data arriving each minute from some instruments rather than each hour. This influx of operational data, products and information has been captured and is available to the world at the Government of Canada's Open Data Portal.

The new Mesonet installed and operated in the Greater Golden Horseshoe Area added close to 60 new automated land and marine stations to the existing monitoring networks. MSC forecasters were selected and trained to support the nuances associated with the Games. Briefers were chosen to provide bilingual in-depth weather briefings based on enhanced atmospheric monitoring data, venue alerts and forecasts. Dissemination of weather conditions and forecasts was the final piece toward having our data and information available to Games organizers, venue managers, coaches and athletes. All select recipients of this information were extremely appreciative of the value of the weather details that were provided.

In support of the Games, research scientists collaborated closely with the Project Team to demonstrate a "Science Showcase" to highlight cutting-edge research and operational capabilities. This Science Showcase comprised several observational, numerical modelling and nowcasting initiatives, and built on the automated stations installed in the Mesonet.

Its design included multiple car-top mobile weather and air quality instrumentation. A high-resolution three-dimensional (3D) total lightning mapping array also covered the Games domain. Scanning Doppler LiDARs and instrumented boats were deployed to support sailing activities, and meteorological instrumentation "supersites" were established to the west and east of Toronto.

A "next generation" forecasting, nowcasting and alerting demonstration was undertaken to evaluate the use of a multi-scale "MetObject" (meteorological graphic object) approach. A number of experimental products were generated relating to convection initiation and severe thunderstorms, which made full use of the Games Mesonet and various meteorological predictions from experimental high-resolution numerical weather prediction and air quality models. Real-time and post-Games verification were also a priority. These showcase products were made available to forecasters and briefers using Web-based applications.

A number of advantages emerged as a result of ECCC's participation in the Games. There was a great deal of partnering and networking required in order to work with our main client, the Toronto 2015 (TO2015) Games Organizing Committee, as well as enablers, partners and stakeholders at different levels of government, academia, media and the private sector. ECCC's presence, delivering the services described above, demonstrated the value and importance of providing detailed weather services for the safety and security of the Games. This increased visibility among partners translated, post-Games, into an appreciation for the suite of service offerings that can and should be used as an essential federal service for all upcoming major events requiring the coordinated efforts of the EFS team.

From the outset of the Project, there was a strong will to take this opportunity, learn from our experiences and strive to improve meteorological services as a result of those lessons learned. The promise was to leave behind a legacy of data, products, information and experiences that, when combined, would not only demonstrate the commitment that was made to show the world ECCC's value-added to the Games but also be of lasting value to Canadians.

The next Pan and Parapan American Games will take place in Lima, Peru, in 2019. It is hoped that ECCC's experiences and lessons learned documented in this report will serve as a useful resource to their meteorological project team as they begin their planning and coordination for their Games.


TORONTO
2015

1 THE MISSION AND MANDATE FOR THE GAMES

The Pan and Parapan American Games are a regional international summer sporting event, staged every 4 years in the year prior to the Summer Olympic and Paralympic Games. The 2015 Games were awarded to Canada on November 6, 2009, by the Pan American Sports Organization. During the summer of 2015, Canada welcomed 40 other countries/nations of the Americas as Toronto and the municipalities of the Greater Golden Horseshoe Area in Ontario hosted the 2015 Pan and Parapan American Games.

The 2015 Pan American Games marked the third time that Pan American Games were held in Canada. The previous two summer Games were held in Winnipeg, Manitoba, in 1967 and 1999. It was Canada's first time hosting the Parapan American Games.

The Pan and Parapan American Games were held from July 10–26, 2015, and from August 7–15, 2015, respectively. Approximately 11,000 athletes, athlete support personnel and technical officials participated in the 2015 Pan and Parapan American Games.

The Government of Canada was 1 of 6 major stakeholders supporting the Games, committing 13 federal departments to provide "Essential Federal Services" (EFS). The remaining major stakeholders were the Toronto 2015 Pan and Parapan American Games (TO2015 Games or Games) Organizing Committee, the Province of Ontario, the City of Toronto, the Canadian Olympic Committee, and the Canadian Paralympic Committee, all of whom worked closely with host municipalities and venue owners.

Environment and Climate Change Canada's (ECCC) mission and mandate for the TO2015 Games was to provide essential services for enhanced weather monitoring and forecasting and for local-level preparedness activities. The key objectives were to enhance public safety and decision making by:

- issuing weather warnings;
- forecasting weather conditions;
- supporting critical weather sensitive government services; and
- monitoring atmospheric conditions.

The funding received by ECCC was used to provide state-of-the-art, 24/7, dedicated, venue-specific weather services during the Games (i.e., 24 hours per day, 7 days per week).


TORONTO 2015
Pan Am/Parapan Am
Pan Am Games: July 10-26, 2015
14
jours
16
heures
59
39
Parapan Am Games: August 7-15, 2015
Jeux parapanaméricains du 7 au 15 août 2015
Juegos Parapanamericanos del 7 al 15 de agosto de 2015
13
jours
06
00
19
POWERED BY
CISCO

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2 EARLY PLANNING

The 2015 Pan and Parapan American Games were awarded to Canada on November 6, 2009, by the Pan American Sports Organization. Soon after the 2010 Vancouver Olympic Games ended, attention in the world of sport turned to the upcoming Pan and Parapan American Games, which were to be held across the Greater Golden Horseshoe Area of southern Ontario in July and August 2015 respectively. Planning for the Games required an early start. Multi-jurisdictional players and partners assembled for this early planning phase, including 13 federal departments, to define the work and associated costs to support the Games.

These 13 federal departments and agencies would deliver on the essential service commitments made by the Government of Canada in a Multi-Party Agreement. The provision of these services related directly to the mandates of the participating departments and agencies. All departments and agencies had been involved, to varying degrees, in past international events, including sport events, such as the Vancouver 2010 Winter Olympic and Paralympic Games.

In 2012, the Federal Treasury Board Secretariat approved the Games submission, and planning started in earnest. The subsections that follow describe in detail the early stages of the ECCC Project.

2.1 TORONTO 2015 PAN AND PARAPAN AMERICAN GAMES AND VANCOUVER 2010 OLYMPICS

The intended outcomes and expected results associated with the Government of Canada's support and investment into the 2015 Pan and Parapan American Games differed from those pursued for 2010 Winter Olympic and Paralympic Games held in Vancouver, British Columbia. The Pan and Parapan American Games are regional Games, limited to countries of the Americas, while the Olympic and Paralympic Games are global in scope, and as such are considered to carry a much higher profile. The Government of Canada's involvement in the Vancouver 2010 Winter Olympic and Paralympic Games sought to leverage the high profile of the event to accomplish "non-sport" goals, including enhancing Canada's domestic and international reputation. Conversely, the federal support for the 2015 Pan and Parapan American Games was mostly safety and sport centred.

While the Vancouver 2010 Winter Olympic and Paralympic Games were bigger in scope, and the Government of Canada's involvement greater, there were parallels between the coordination role of the Federal Secretariat in the 2010 Olympic and Paralympic Games and that of the Department of Canadian Heritage for the 2015 Pan and Parapan American Games. As a result, the Government of Canada's experience in hosting the Vancouver 2010 Olympic and Paralympic Games informed the approach for the planning and coordination across the Government of Canada for this type of event. In some cases, the 2015 Pan and Parapan American Games Project Team adopted some of the approaches to federal coordination that were used by the 2010 Federal Secretariat, and in other situations the approach was modified and scaled to match the complexity of coordinating federal involvement in a smaller event. The most significant difference relating to federal involvement is that the federal government was not leading the security efforts for the 2015 Pan and Parapan American Games, as was the case for the Vancouver 2010 Olympic and Paralympic Games. The Province of Ontario and specifically the Ontario Provincial Police were responsible to lead the security for the 2015 Pan and Parapan American Games.

The ECCC 2015 Pan and Parapan American Games Project Team used a similar governance structure as was implemented for the Vancouver 2010 Winter Olympic and Paralympic Games, notably an Essential Federal Services Working Group, which was struck by Sport Canada and committees at the Assistant Deputy and Deputy Minister levels. However, for the 2015 Pan and Parapan American Games, additional working groups were created on an as-needed basis, and the more senior committees were called upon where the approval or direction of Deputy Heads was warranted.

2.2 TREASURY BOARD SUBMISSION

ECCC (formerly Environment Canada) derives its mandate from the *Department of the Environment Act*, which requires implementing environmental legislation, policies and programs to protect, maintain and enhance the quality of the natural environment. It also requires that Canadians are provided with the information they need to make informed decisions to protect their health, safety and security, and economic prosperity in the face of changing weather and environmental conditions.

Flowing naturally from the Department's mandate, during the creation of the Treasury Board Submission, ECCC had to capture its mission and contributions to the Games. This mission was to provide essential services for enhanced weather monitoring and forecasting, for local-level preparedness activities, and to support environmental assessments of projects relating to the Games. The Treasury Board Secretariat granted ECCC funds starting in 2012 to provide these essential services specific to the Games that were outside the normal scope of duties for the Department, hence the requirement to ask for additional Treasury Board funding for the Project. These funds were spent primarily by the Meteorological Service of Canada (MSC) to provide enhanced weather monitoring, state-of-the-art, 24/7 venue-specific forecasts, weather warnings, watches and advisories, and support to critical weather-sensitive government services to ensure the safety and protection of athletes, staff, volunteers and spectators.

ECCC also provided essential services to engage in local-level preparedness activities associated with the Games. As per normal operations, 24/7 response support was provided during the Games. With the incremental funding that was sought in the Treasury Board Submission, additional prevention and preparedness activities were undertaken under the Environmental Emergencies Program. The key objectives of the Program were:

- to review responsibilities under the Federal Emergency Response Plan, and to deliver environmental emergency advice to other agencies during preparedness events and exercises;
- in the event of an environmental emergency, to deliver services and coordinate with other agencies in the monitoring and/or coordination of a response;
- to identify project components regulated by the *Canadian Environmental Protection Act*, *1999's Environmental Emergency Regulations*, in close proximity to venues, and to conduct site visits to audit environmental emergencies plans;
- to provide compliance promotion as needed; and
- to identify consequences of incidents at those facilities.

In addition, ECCC provided specialist and expert information or knowledge in support of federal and provincial environmental assessments of projects related to the Games, under the Environmental Assessment Program. The Program was responsible for meeting its obligations under the *Canadian Environmental Assessment Act, 2012* and other federal environmental assessment processes. It supported responsible authorities who were required to complete environmental assessments, through the provision of scientific and technical advice regarding ECCC's mandated areas of responsibility (water and air quality, migratory birds, species at risk, etc.) in support of federal environmental assessment reviews.

The key objectives of the Environmental Assessment Program were:

- to ensure that decision-makers were provided with timely, scientifically sound, relevant information ensuring environmentally sound decisions were taken when planning projects, policies and programs; and
- to promote compliance with the *Canadian Environmental Assessment Act, 2012* and provide high-quality advice to other federal departments, provinces and other agencies.

This report focuses on the MSC mission for the Games, which included contributions from ECCC's Science and Technology Branch.

2.3 CLIMATOLOGICAL INFORMATION FOR THE GAMES

Weather can play an important role in safety and logistics decisions made by organizers of sports events. For major events, such as the Olympics or the Pan and Parapan American Games, information on long-term weather conditions and historical weather extremes can also be used to support planning and decision making well in advance of the Games. To meet the anticipated climatological needs of the TO2015 Games organizers, in 2013 and 2014 the ECCC 2015 Games Project Office developed a series of detailed climatologies for Ontario, with a specific focus on the southern Ontario 2015 Games area. The detailed climatologies provide information at the provincial, regional and site-specific scale for seven different parameters:

- tornadoes;
- heat and humidex;
- lightning and days with thunderstorms;
- extreme rainfall;
- wind;
- lake breeze; and
- Air Quality Health Index.

Long-term averages, extremes, number and type of occurrences were investigated, with results provided in graphic and tabular format. A summary climatological document was also prepared specifically for TO2015, again anticipating their needs. When TO2015 officially requested ECCC to provide climatological information in 2013 and 2014, the Project Office was able to quickly respond to their request and provide the required information. Highlights from the climatologies were selected by TO2015 and published prior to the Games in 2015 within their Team Guides (for the athletes and officials of the National Olympic and Paralympic Committees) and Technical Officials Guides (for the judges and referees appointed by the international and continental federations). Sample climatological graphics for heat, humidex, wind and extreme rainfall are provided in Figure 1.

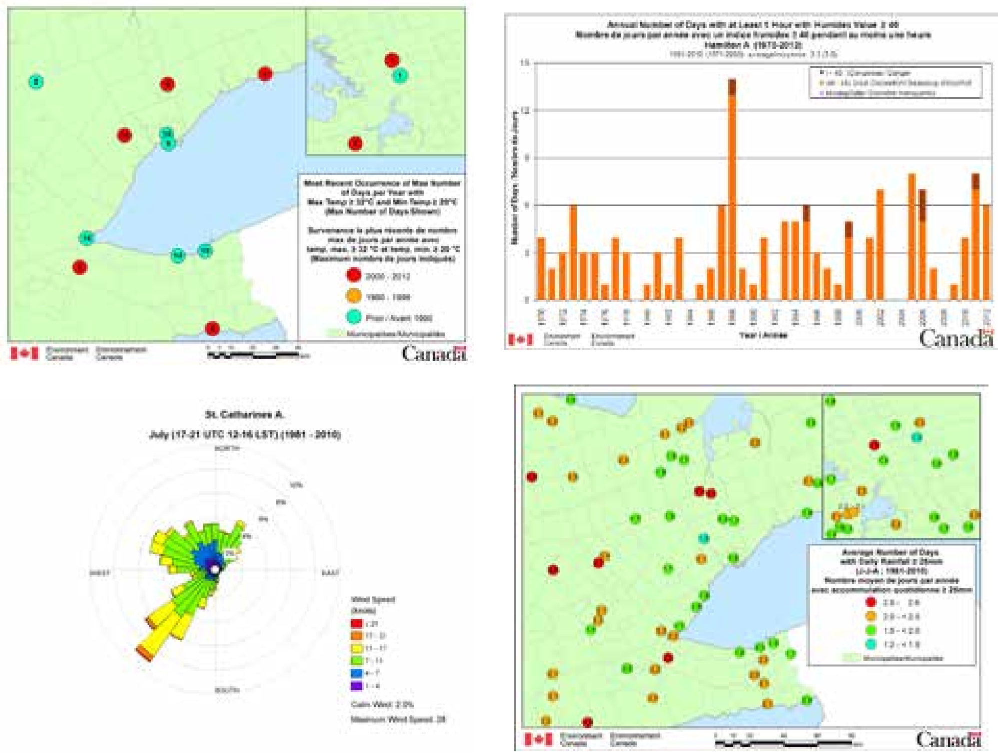

Figure 1. Sample weather station–specific and Games region climatological graphics, clockwise from top left: a) map showing most recent occurrence and maximum number of days per year with extreme “Heat Events” (maximum temperature ≥ 32°C and minimum temperature ≥ 20°C) (stations’ period of record through 2012); b) annual number of days (1970–2012) at Hamilton Airport with humidex ≥ 40; c) Wind “Rose” for St. Catharines Airport showing average (1981–2010) frequency of occurrence of afternoon winds from different wind directions; and d) map showing average (1981–2010) number of summer days with daily rainfall ≥ 25 mm.

The climatologies were also included as part of a series of internal training workshops for operational forecasters and briefing team members who supported the Games. Finally, information from the climatologies was used in the Federal Risk Assessment for the Games to assess the impacts and likelihood of weather-related hazards. The climatological documents are part of the legacy from the Games as the new and updated information continues to be used by forecasters, briefing services and warning preparedness meteorologists in the normal Ontario operations forecast and alerting program.

2.4 WEATHER SENSOR INTERCOMPARISON STUDY

As part of an enhanced monitoring initiative in support of the Games, ECCC increased the number of weather monitoring stations and their temporal resolution across southern Ontario’s Greater Golden Horseshoe Area. The high-resolution monitoring system, known as the Mesonet, was comprised of over 50 new land- and marine-automated weather stations, including 40 compact stations (see Section 5). An automated weather sensor intercomparison study was initiated in 2012 during the Mesonet planning stages to assess the performance of automated compact weather stations that would be used in the Mesonet and potentially in the MSC core monitoring networks of the future. In this study, data from 5 compact weather stations installed at ECCC’s Egbert, Ontario, Centre for Atmospheric Research Experiments (CARE) test facility was compared with data from co-located MSC Reference sensors. Study results were used in decisions for selection of compact weather station types for the Mesonet. The results also helped increase our knowledge of data quality from different types of weather stations that could potentially be installed within a Network of Networks Mesonet of the future (i.e., this includes data from external partner agencies as well as data from the MSC; see Section 5.8.2).

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Figure 2. Three types of compact weather stations assessed in ECCC's intercomparison study: Vaisala WXT520, Lufft WS601 All-in-One and Climatronics All-in-One.

2.5 THE GAMES FOOTPRINT

The highlighted regions within Figure 3 show the large footprint where Games operations took place. The location of the Games venues in the Greater Golden Horseshoe Area of southern Ontario are shown within ECCC's existing public forecast regions. Locations with venues within short distances of each other were considered as a single point or a venue "cluster" for the purposes of our new point-forecasting technique (see Section 8.1). In total, there were 20 "points" identified to represent all of the competition venue locations for which a venue or venue cluster forecast and alerting program would be provided. There were other locations that were used for ceremonies, media, and Panamania arts and crafts festival. However, these locations were not included on this map and were not the focus of point forecasts. Instead, they simply fell within ECCC's standard public forecast regions.

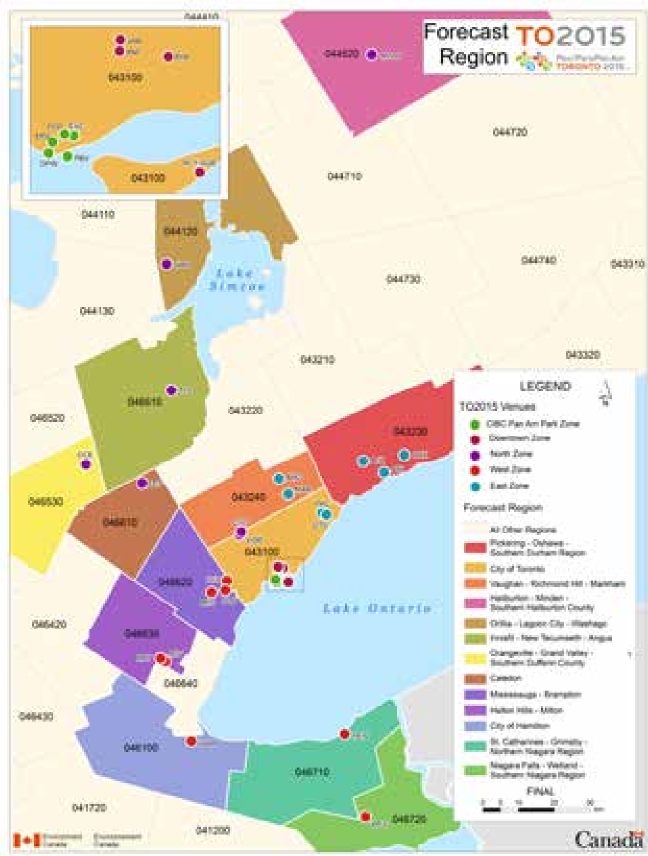


Figure 3. TO2015 Games venues in TO2015 defined zones, overlaid on ECCC's public forecast regions.

3 THE PROJECT TEAM

From the Project's inception through to its closure, close to 450 people made contributions to ECCC's project to ensure the success of the delivery of services to the TO2015 client. A small expert team representing monitoring, prediction and services, science, and information technology was initially formed to craft, negotiate and document ECCC's contributions to the Games in the Treasury Board Submission. Once funding was received in 2012, the Steering Committee, Project Board and three different Working Groups (Monitoring, Prediction and Services, Science) were formed. A Project Lead was identified within ECCC, and a Project Office Manager and Project Assurer chosen to lead and coordinate the work prior to, during and after the Games. An Information Management/Information Technology Working Group was created in 2013. Lastly, as the Project moved towards implementation and final preparations for the Games, the Implementation Team was assembled in 2014.

3.1 STEERING COMMITTEE

A Steering Committee was formed in 2012 to provide oversight management of the Project at an executive level. Although the membership of this Committee changed over the years, the overall executive leadership of the Project remained with one Director General and one Director for the sake of consistency and continuity. Some members retired or moved to other functions within the Department, and because of the functional reporting of the Working Groups, the selection of the Steering Committee members had to include executive members of the core services and operations of the organization in order to mobilize staff to work on the project.

Steering Committee members realized, understood and appreciated the high profile of the project relating to the safety and security requirements of the Games and the interactions necessary with other federal colleagues. Furthermore, they planned for this multi-disciplinary team to continue working on their component parts across as many as five fiscal years.

3.2 PROJECT BOARD

In early 2013, ECCC adopted a more rigorous standard as the number of players and tasks grew. The project management "industry" subscribes to many methodologies, and ECCC had selected the PRINCE2® methodology to be the internal industry-standard used. The Project Office for the Games adopted a "PRINCE2®-lite" approach in order to help formalize and run a much more structured project. The team was able to isolate the management aspects of project work from the specialist contributions, such as design and construction. The specialist aspects of the Project were easily integrated with this method to provide an overall framework for the Project. The technique is generic and based on proven principles, so that organizations that adopt the method substantially improve their organizational capability and maturity across various areas such as business change, construction, IT, and research and product development.

The Project Board was formed to be accountable to corporate or program management for the success of the project and had the authority to direct the project as documented in the project mandate. The Project Board was also responsible for the communications between the project management team and stakeholders external to that team.

3.3 PROJECT WORKING GROUPS

The Project Office began by developing a plan based on the approved Treasury Board submission and identifying a number of functional leads for working group teams that had to be assembled in order to accomplish the Project's mission. The Working Groups became supporting pillars to the Project overall and used human resources with specific skills from many parts of the organization. The Project Lead and Project Office team were members of all of the Working Groups, ensuring the coordination and integration of work between the different groups.

3.3.1 MONITORING WORKING GROUP

The purpose of the Monitoring Working Group, formed in 2012, was to make decisions with regard to network design, data collection, data acquisition, data storage and data transmission related to the atmospheric monitoring effort in support of the Games. This included the data that was collected for real-time forecast operations, scientific studies and validation of research initiatives. The Monitoring Working Group had the authority to approve the design of the Games monitoring effort within the scope defined by the Games business plan, which flowed from the Treasury Board approval.

3.3.2 PREDICTION AND SERVICES WORKING GROUP

The purpose of the Prediction and Services Working Group, formed in 2012, was to coordinate and manage the services and products (weather and environmental alerts and forecasts) that were provided by ECCC in support of the Games. This included defining the users/clients, both internal and external, and working with them to ensure that their requirements were met. There were many types of potential bulletins, clients and perspectives involved with this process. It was very important that all systems and personnel be in place well ahead of time for proper testing before the Games began. The group made recommendations regarding the best projects to pursue, taking into account the resources available and the clients' needs.

3.3.3 SCIENCE WORKING GROUP

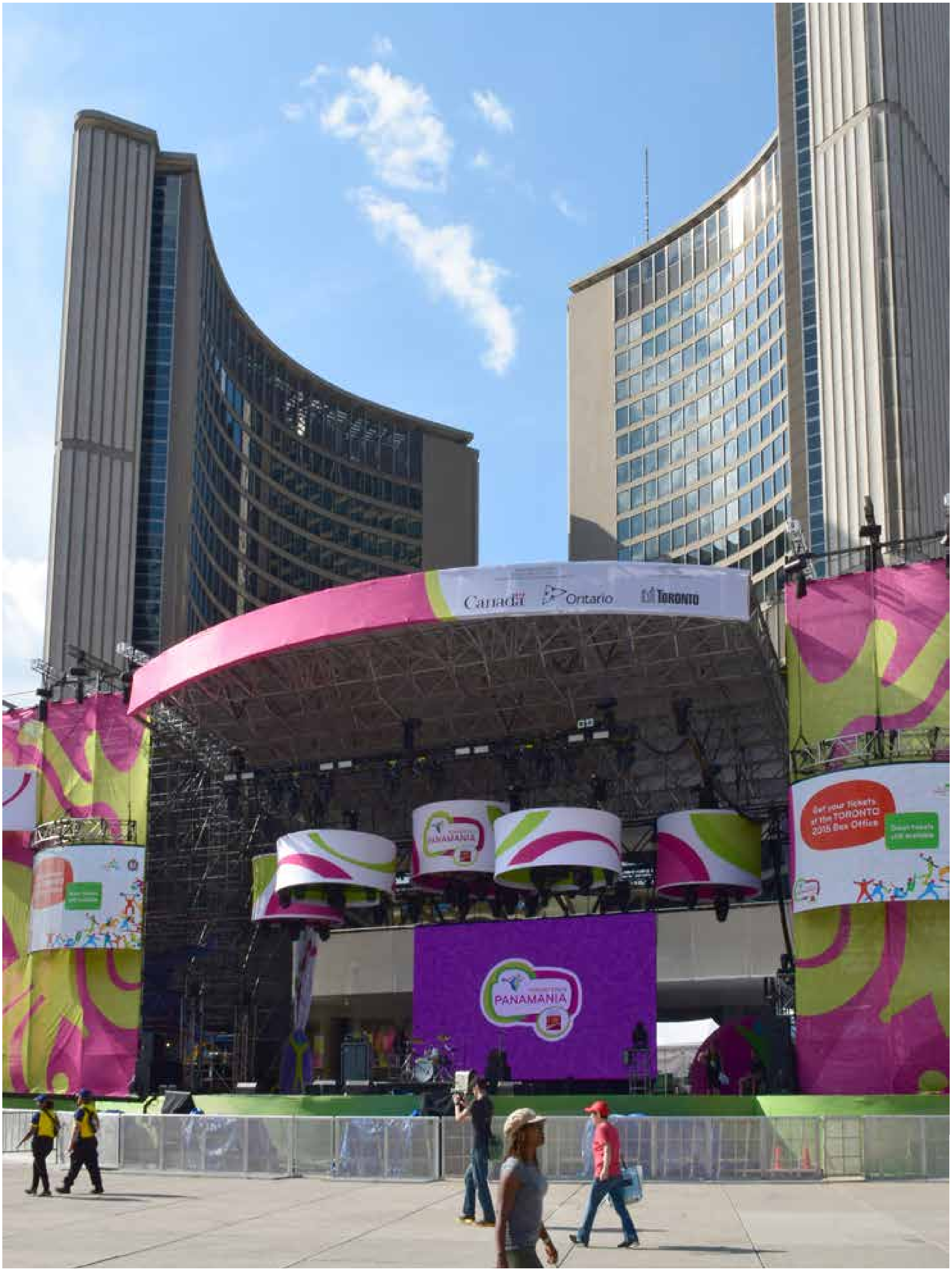
The purpose of the Science Working Group, formed in 2012, was to provide leadership for all of the scientific and showcase projects that scientists contributed in their support to the Games. The group managed the user requirements from a science perspective and determined what could be showcased during the Games. The science team noted opportunities and leveraged resources to develop high-resolution forecast models, extend the Mesonet for high-resolution and current numerical weather prediction model validation, and produce new and emerging nowcasting and forecast dissemination tools.

3.3.4 INFORMATION MANAGEMENT/INFORMATION TECHNOLOGY WORKING GROUP

The purpose of the Information Management and Information Technology (IM/IT) Working Group, formed in 2014, was to record, track and oversee the delivery of IM/IT services in support of the Games. Over the course of the planning and implementation period, it recorded and tracked requests for any Games-related IM/IT services, planned tasks and performed oversight. This Working Group also coordinated communications between all Working Groups to maintain cohesion with the work being done for the end-to-end functionality of systems from monitoring through to dissemination.

3.3.5 IMPLEMENTATION TEAM

As the Project moved from initial planning stages to implementation, an Implementation Team was formed in 2014 with representation from Ontario monitoring, prediction, services, IT and science management. These managers had roles in each of the larger Working Groups to help plan tasks that their resources would execute. This committee was the implementation arm of the overarching plans created by the Working Groups to produce the products and services required by the client.


Canada
Ontario
TORONTO
PANAMANIA
PANAMANIA

4 ENVIRONMENT AND CLIMATE CHANGE CANADA'S PARTNERS FOR THE GAMES

The entire operation of the Games would not have been successful without the contributions of expertise from all levels of government, from the private sector and from the team of individuals who were assembled to bring all facets of the Games operations to light. With the venues spread across the Greater Golden Horseshoe Area of southern Ontario, there was a requirement for ECCC to engage with many partners in each of the municipalities and regions. The Ontario Government was given accountability for safety and security, while 13 federal departments, including ECCC, played their parts as EFS contributors to the smooth execution of the Games.

4.1 TO2015 MAIN OPERATIONS CENTRE

The Toronto Organizing Committee for the 2015 Pan and Parapan American Games (TO2015), was a non-profit organization responsible for producing and financing the Games. Their Main Operations Centre (MOC) was the planning and operational headquarters for both Games. The individuals at the TO2015 MOC were identified as those required to be in the "hub" of activities of the Torch Relays and the Games. The office was physically located in the Corus Quay building at Toronto Harbourfront, a few kilometres away from the venue clusters in Toronto's downtown, to maintain oversight for all venues from a central location. From here, resources could be dispatched to any venue requiring assistance, transportation aid or material items such as radio transponders.

A formal Service Level Agreement (SLA) was drafted between ECCC and TO2015. The SLA defined the general principles of cooperation created between the participants undertaking technical and expert service-related activities as part of the cooperative alliance between ECCC and TO2015 during the Games. It detailed the obligations of each participant, the types of products and services expected by each, and the support response times required in order to maintain operations efficiently and effectively. By mid-April 2015, the approved SLA was signed by representatives of both organizations (see Figure 4).

As a result of the signed agreement, ECCC situated its briefing team at the TO2015 MOC to support the operation of the Games directly. Inside the MOC, daily briefings were held with updates from all partners. The first briefing of each morning was particularly important, as it described perspectives on issues and events of the day including the effects of weather, where appropriate.

Figure 4. ECCC's Project Lead (left) and the TO2015 Senior Manager of Sport Services sign the Service Level Agreement on April 9, 2015.

4.2 ESSENTIAL FEDERAL SERVICES

The Government of Canada, through the *2015 Pan/Parapan Games Multiparty Agreement* (MPA), committed funding for capital projects, legacy initiatives and Essential Federal Services (EFS) in support of the Games. The Department of Canadian Heritage, through Sport Canada's Hosting Program Division and Federal Secretariat, was responsible for ensuring and supporting collaborative, coordinated planning; overseeing integrated horizontal risk and performance management; and overall reporting in relation to the federal investment in the Games.

The Department of Canadian Heritage, as the lead department for federal involvement in the Toronto 2015 Games, acted as the horizontal project coordinator and chaired the Essential Federal Services Working Group (EFSWG). Thirteen federal departments, including ECCC, were identified as EFS for the Games, and had representation on the EFSWG (see Table 1). Canadian Heritage, in consultation with other departments, agencies and Multi-Party Agreement (MPA) parties involved in the planning of EFS, determined when planning, performance or risks dictated the need to bring items to the EFSWG. They also determined when to elevate items to senior officials for decision and direction to ensure that MPA EFS commitments were achieved.

The objective of the Working Group was to provide a forum to support coordinated and integrated planning and reporting across federal departments and agencies for the horizontal elements of the Government of Canada's investment in essential federal services for the Games.

The EFSWG facilitated EFS delivery for the Games by supporting horizontal planning, performance, risk and issue management across all EFS service areas, federal departments, agencies and MPA parties, as well as supporting federal accountability and reporting in relation to EFS commitments.

The federal services were grouped into the following four service areas:

Table 1. Federal Service Areas and Organizational Interests

SERVICE AREA	ORGANIZATIONAL INTERESTS
Weather Forecasting and Environmental Assessments	Environment and Climate Change Canada
Emergency Preparedness	Public Safety Canada Public Health Agency of Canada Health Canada Canada Border Services Royal Canadian Mounted Police Fisheries and Oceans Canada Canadian Security Intelligence Service Transport Canada Environment and Climate Change Canada
Security	Royal Canadian Mounted Police Canadian Security Intelligence Service Public Safety Canada Transport Canada Innovation, Science and Economic Development Canada Fisheries and Oceans Ocean Immigration, Refugees and Citizenship Canada Canada Border Services
Border Security and Accreditation Support	Canada Border Services Canadian Security Intelligence Service Immigration, Refugees and Citizenship Canada Royal Canadian Mounted Police

Departments and agencies used the existing infrastructure within their organizations and across government to determine if the security threat or risks to the environment had changed in the lead up to, during and immediately after the Games. They followed established protocols and procedures to determine and respond to any elevation in any security threat.

4.3 PROVINCIAL EMERGENCY OPERATIONS CENTRE

The provincial Government of Ontario was responsible for the safety and security of the Games, for which the Ontario Provincial Police had the lead. The Office of the Fire Marshal and Emergency Management was the lead agency for directing and coordinating Ontario's consequence management strategy for the Games.

The Government of Ontario's 24/7 Provincial Emergency Operations Centre (PEOC) monitors evolving situations inside and outside of Ontario. This ensures that key decision-makers and provincial resources are able to respond to evolving situations as quickly as possible. The key function of the PEOC is to coordinate Ontario Government response to major emergencies. This includes providing municipalities and First Nations with a single point of contact for provincial assistance in times of crisis. The mission of the PEOC during the Games was to effectively coordinate provincial consequence management activities in response to any large-scale incident or event that may have affected the safe and successful completion of the Games and may have required coordination of provincial resources. The PEOC was the provincial hub for consequence management planning and consequence management information sharing with Games stakeholders.

Inside the PEOC, the coordination of the security risks and concerns were handled daily. As part of its standard forecast and alerting program, ECCC provides the PEOC with daily email weather updates to facilitate their decision making, with more frequent updates as required. This procedure continued during the Games.

4.4 UNIFIED COMMAND CENTRE

The Unified Command Centre (UCC) was the policing headquarters set up specifically for the Games in Brampton, Ontario, and was the hub of all Games policing and security. The Ontario Provincial Police created an Integrated Security Unit to provide on-site security-related expertise and liaison among security partners to ensure consistency and coherency in operations. Within the UCC, ECCC worked through the Royal Canadian Mounted Police (RCMP) to support policing activities for the Integrated Security Unit. Police forces undertaking special activities would ask for forecasts and weather conditions in localized regions within the Games footprint.

Although there was no formal signed agreement, ECCC situated another briefing team at the UCC to support policing and security activities for the Games. Inside the UCC, daily briefings were held, with updates from all relevant police jurisdictions.

5 THE MESONET

This section focuses on the foundational piece of the Project on which the rest of the IT infrastructure and meteorological services were built: the atmospheric monitoring network known as the Mesonet. This high spatial and temporal resolution network was comprised of new automated land- and marine-based weather stations, and additional experimental monitoring platforms. ECCC designed the Mesonet to monitor weather at the venues, while providing close tracking of southern Ontario lake breezes, which can be associated with severe weather initiation and high air pollutant concentrations. Knowledge about lake-breeze location would also increase our understanding of heat and air quality patterns, particularly in the urban environment.

The section begins by defining the operational monitoring network and then proceeds to describe, in detail, the technologies that were put into place to develop a world-class, urban-scale network that performed beyond expectations during the Games. There was an entirely separate network of science-related monitoring that was created for research purposes. The science components are discussed in detail in Section 11.

5.1 MESONET – DEFINITION

ECCC's forecast, alerting and monitoring efforts in support of the Games were heavily dependent on a new and enhanced atmospheric monitoring Mesonet installed across southern Ontario. The instrumentation in the Mesonet is described in greater detail in later subsections of Section 5, while the general concept of a Mesonet is described below.

"Mesonet" combines the words "mesoscale" and "network," where "mesoscale" refers to a scale of between a few kilometres to several hundred kilometres. Within ECCC, and the field of meteorology in general, a Mesonet is a network of weather stations designed to observe mesoscale meteorological phenomena. Mesoscale weather events or phenomena range in horizontal scale from generally 1 km to 250 km, with time spans from several minutes to several hours.

An atmospheric Mesonet can provide high-resolution detection and tracking of mesoscale features such as lake breezes, convective rainfall events (i.e., showers, thunderstorms), urban heat islands (see Section 8.5.1) and other fine-scale weather phenomena. The small areal size and short time scales of most of these phenomena drive the Mesonet design, requiring closer spacing of the weather stations and higher frequency reporting than what presently exists in observing networks.

As with the phenomena it is designed to detect, our ECCC Games Mesonet was short-lived, with almost all stations decommissioned in fall 2015.

5.2 DESIGN OF THE MESONET

The Treasury Board document directed ECCC to provide enhanced weather monitoring and venue-specific weather warnings, watches and advisories to ensure the safety and protection of athletes, staff, volunteers and spectators during the 2015 Games (see Section 2.2). ECCC worked closely with the TO2015 Host Committee and sport organizations to identify sport-specific and venue-specific needs and reconcile against gaps in existing forecasting and atmospheric monitoring locations. The initial design of the Mesonet was centred on limiting station installations to sporting venues.

ECCC scientists expanded the Mesonet design to better track the lake breezes across the Games footprint. The proposed Mesonet met all operational requirements while also providing a unique research opportunity for scientists.

The data from the Mesonet would be used to inform the weather forecasting and alerting program for the Games and a "next generation" weather forecasting demonstration at two Research Support Desks (RSDs) within the Ontario Storm Prediction Centre (OSPC) in Toronto (see sections 8.1 and 8.2). It also provided some verification data for new, high-resolution numerical weather prediction models.

The existing weather monitoring networks across southern Ontario have a heavy reliance on NAV CANADA and the Department of National Defence (DND) for the provision of observations, with ECCC automated stations comprising the remainder. To push the limits of the data acquisition without impacting forecast or monitoring operations, ECCC would need to build, install and operate a Mesonet that could be controlled and isolated for test and evaluation. The Mesonet that was subsequently built provided both high-density station spacing and high-frequency minute-by-minute reporting. It reported standard meteorological variables, as well as new elements such as black globe temperature (used in evaluation of heat stress on the human body).

To track the lake breeze, existing land and marine monitoring capacity was identified (Figure 5) and expanded to define the Mesonet. This took into consideration our commitment to add an atmospheric monitoring station to any Games venue that did not fall within three kilometres of an existing station. The new monitoring "lines" became the numbered transects that would comprise the Games Mesonet. A total of six transect lines were defined, as shown on the Mesonet map in Figure 6.

ECCC then looked internally for capacity to build the Mesonet. Ten Automated Transportable Meteorological Observing System (ATMOS) stations were refurbished, and new processing software was provided. Forty compact stations were built from commercially available parts using an in-house design. Installation on private land required that each station have a land lease or a land use permit. To minimize real estate negotiations, the compact stations were designed to be stand-alone, i.e., not requiring connection to utilities or any disruption of the host site. To minimize costs and maximize the Mesonet, a significant number of dataloggers and instruments were drawn from national inventory. ECCC committed to a proposal to use the Games Mesonet to test and evaluate a new end-to-end monitoring data acquisition system that could modernize the existing system post-Games. As part of the Games legacy, ECCC installed three standard automated MSC Auto8 weather stations (Uxbridge West, Mono Centre and Brantford) across southern Ontario. The intent was to provide the best locations to suit the Games monitoring requirements while meeting long-term national monitoring goals for weather observations across the Greater Toronto Area (GTA). These stations permitted ECCC to test and evaluate new datalogger software, new reporting formats and increased reporting frequency without impinging on operational stations. All aspects of the modernization of data collection and processing were completed with the full support of IT experts under the auspices of the ECCC Data Management System. All work completed was fully tested and certified for use on the operational networks, making it available for use by existing MSC networks post-Games, should they so desire.

The new automated surface weather stations were configured to report every minute, a sharp departure from the standard hourly reporting. The minute-by-minute reporting was successfully implemented at all 53 new automated weather stations in the Mesonet. The map of the Mesonet below shows the location of the stations.

The planning, building and deployment of these stations took three years. Most of the work was easily understood and attributable. However, the information management aspect of the Project contributed greatly, in fact was mission critical, extensive in nature, and complex.

Figure 5. Map showing the location of stations reporting hourly weather observations in the existing atmospheric monitoring network prior to the TO2015 Games.

Figure 6. Map showing the location of stations in the Mesonet, the new enhanced atmospheric monitoring network for the Games.

5.3 NEW AUTOMATED SURFACE WEATHER STATIONS

As described in Section 5.2, ECCC added 40 compact stations, 10 ATMOS stations and 3 standard automated MSC Auto8 stations to the existing networks to form a high-resolution monitoring system across southern Ontario known as the Mesonet. Photos of 4 of these new stations are shown in Figure 7. These stations provided both high-density spacing and high-frequency minute-by-minute observations. Standard meteorological variables were reported—atmospheric pressure, wind speed and direction, relative humidity, temperature and precipitation amounts—as well as a new element recorded by a black globe thermometer, used in the evaluation of heat stress on the human body.

The stations used solar cells for power and a cellular modem for communication. The standalone design allowed for an easy installation at temporary locations and for a simple decommissioning process after the Games. For the first time, ECCC collected weather conditions minute by minute in contrast to the hourly reports provided from standard network stations.

As with so many technologies, weather instrumentation has decreased in size and cost rather quickly, while maintaining much of its robustness and measurement accuracy. While these stations could not replace a standard ECCC automatic station at this time, they could provide affordable and dependable measurements from locations previously beyond consideration. These stations have low power consumption, allowing the use of solar panels and batteries. They are compact and lightweight, allowing for easy installation. With the 2015 Games, the timing was right for ECCC to use these compact stations to measure weather conditions at the venue sites while evaluating their utility as a measurement platform for the provision of high-resolution data for dense urban areas. The stations in the Mesonet made it possible to measure conditions on a finer scale in order to validate the high-resolution urban modelling work being done at ECCC's Canadian Meteorological Centre (CMC) in Montréal, Quebec.

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Figure 7. Clockwise from top left: ATMOS, Vaisala WXT520, Lufft WS600, WS601 weather stations.

5.4 WATCHKEEPER™ BUOY

An AXYS WatchKeeper™ buoy was one of two buoys deployed south of the Toronto Islands to provide meteorological and wave observations in support of the Lake Ontario open water events at the 2015 Games (see Figure 8).

The AXYS WatchKeeper™ buoy is a self-contained, solar-powered data acquisition system outfitted with a suite of meteorological and oceanographic instrumentation to measure wind speed and direction, air temperature, atmospheric pressure, water temperature, and wave height, period and direction. This WatchKeeper™ buoy is the first in Canada outfitted with a cellular modem to enable the transmission of weather reports every 10 minutes (standard is once per hour), directly to CMC in Montréal.

Figure 8. The WatchKeeper™ Buoy before being deployed in Lake Ontario, south of the Toronto Islands.

The Games hosted a number of open-water events in the inner harbour and south of the Toronto Islands, an area where the competition or logistics could be affected by thunderstorms, severe weather or heat stress. This buoy was part of the Mesonet system of additional monitoring technologies, with higher than standard temporal reporting, put in place to inform the ECCC forecast process. The more frequent reporting of marine weather conditions was a test and evaluation designed to determine whether it could provide an improvement in marine forecast accuracy or response times for alerts during active marine weather conditions.

5.5 TRIAXYS™ DIRECTIONAL WAVE BUOY

The TRIAXYS™ Directional Wave Buoy incorporates new technologies that increase the accuracy of measurement of wave height, wave period and wave direction. The TRIAXYS™ buoy was an outcome of a collaborative program between AXYS International Inc. of Sidney, British Columbia, and the Canadian Hydraulics Centre of the National Research Council in Ottawa, Ontario.

Unlike standard MSC lake buoys, the TRIAXYS™ Directional Wave Buoy reports specialized wave information but not weather observations. At less than 200 kg, this buoy can respond quickly to waves, including the smaller waves that do not register on our heavier buoys such as the WatchKeeper™. Its small size and light weight permit the use of small craft for deployment, a significant cost saving. This buoy transmitted data to CMC every 30 minutes by cellphone. These data were used to validate output from the new high-resolution wave models developed by CMC while also giving weather forecasters more-frequent, higher-resolution wind, wave and weather information. Post-Games, the TRIAXYS™ Directional Wave Buoy will be deployed into the ECCC operational network for ongoing support of the CMC wave modelling program. The buoy is expected to provide new insights into near-shore wave conditions and a surer response to wave conditions that affect small craft.

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Figure 9. The TRIAXYS™ Directional Wave Buoy before being deployed in Lake Ontario, south of the Toronto Islands.

© John MacPhee

Figure 10. KIPP & ZONEN UVS-AE-T sensor (UV radiometer) shown next to a cellphone, to demonstrate the small sensor size.

The efficacy of the wave measurement by the buoy will permit marine services to consider its utility for reporting under-keel clearances in active weather. Accurate wave height measurement allows the safe transit of deep draft ships or ships in heavy weather, especially when navigating a harbour entrance.

5.6 ULTRAVIOLET STATIONS

Four ground-based radiometers (ultraviolet radiation instruments) were deployed in the Greater Golden Horseshoe Area in support of the Games (see Figure 6 for instrument locations and Figure 10 for a photo of the instrument). They reported minute-by-minute observations of the ultraviolet (UV) component of sun exposure as defined by the Global Solar UV Index (UVI). The ultraviolet index or UV Index is an international standard measurement of the strength of sunburn-producing UV radiation at a particular place and time. The scale was developed by Canadian scientists in 1992, then adopted and standardized by the United Nations' World Health Organization and World Meteorological Organization in 1994.

The readings from these sensors were used to inform the operational forecast program, particularly to provide data for validation of the UV index forecasts from the ECCC numerical modelling system (see Section 11.5).

5.7 UPPER AIR TRAILER

During the Games, ECCC used its existing emergency Upper Air trailer to release upper air balloons equipped with radiosondes. Radiosondes are small instrument packages comprised of a radio transmitter and sensors to measure pressure, temperature and humidity as the balloon travels up through the atmosphere. The information collected from upper air observations is essential to create a global overview of the current and future state of the atmosphere.

Four radiosondes per day were released from a mobile Upper Air trailer located at ECCC's King City radar location, north of Toronto (see Figure 11). As deployed, this trailer constituted an expansion to the national Upper Air network for the 27-day period of the Games. The four releases per day from this trailer contrast with two


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Figure 11. ECCC monitoring staff launches an upper air balloon at its King City radar location. The Upper Air trailer is on the left of the photo.

launches per day at a standard Upper Air monitoring station. This additional upper air data was used to perform a detailed analysis of atmospheric conditions across southern Ontario during the Games.

The Games served as a catalyst for ECCC to modernize the Upper Air trailer and the communications technologies that are used at all mobile Upper Air trailers across Canada. These trailers are used on an as-required basis, particularly during environmental emergencies.

5.8 PARTNER SUPPORT

A great deal of work was accomplished with the help of our partners, who were dedicated to the Project from its inception. The success stories described below demonstrate the power of partnerships in enhancing weather and air quality observations in the Mesonet.

5.8.1 AIR QUALITY STATIONS

ECCC collaborated with the Ontario Ministry of the Environment and Climate Change (MOECC), York University and the University of Toronto to implement a study of traffic-related air pollution. The primary objective was to evaluate the utility of a network of air quality monitoring stations to assess and understand the levels of traffic air pollution in major Canadian cities. As part of the study, four new comprehensive monitoring stations were established in Toronto in advance of the Games. The stations are designed to operate in pairs, with one located near a major roadway, while the second is located away from any roads, such that it served as an urban background measurement. This configuration allowed researchers to track air quality changes as air-masses crossed the city and to characterize the pollutants originating from traffic on the major Highway 401 and in a typical downtown Toronto situation.

In addition to pilot studies on traffic air pollution, which are also under way in Vancouver, the data from this new network of stations provided air quality information to support the Games. Observations of ozone (O_3), fine particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) were sent to the MOECC to produce the AQHI, which was transmitted as part of the ECCC forecasts issued in support of the Games. These new AQHI reports augmented the reports already being produced from the long-term air quality network in the Toronto region (see Section 12.2.1) and throughout Ontario. The AQHI replaced the Air Quality Index on June 24, 2015, just prior to the start of the Games.

5.8.2 NAV CANADA STATIONS

Nine NAV CANADA monitoring stations (i.e., airport locations) fell within ECCC's Mesonet footprint in southern Ontario, mostly at high-visibility locations where increased temporal reporting would be clearly beneficial. Upon request, NAV CANADA agreed to provide automated minute-by-minute reports from their Automated Weather Observing Systems (AWOS) and Human Weather Observing Systems (HWOS) stations. These observations were made available to forecasters, briefing teams, security services, the TO2015 organization, sports organizations and athletes. All clients reported that the increased reporting frequency was useful and insightful, particularly so during times of active weather.

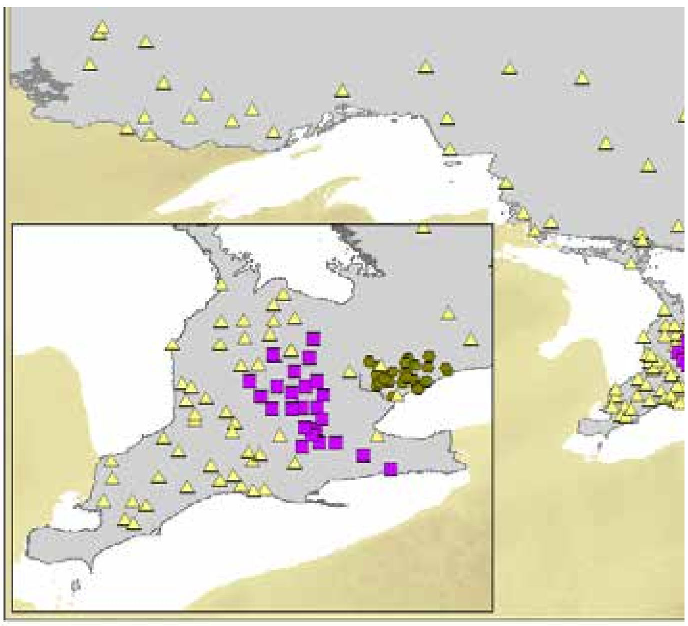
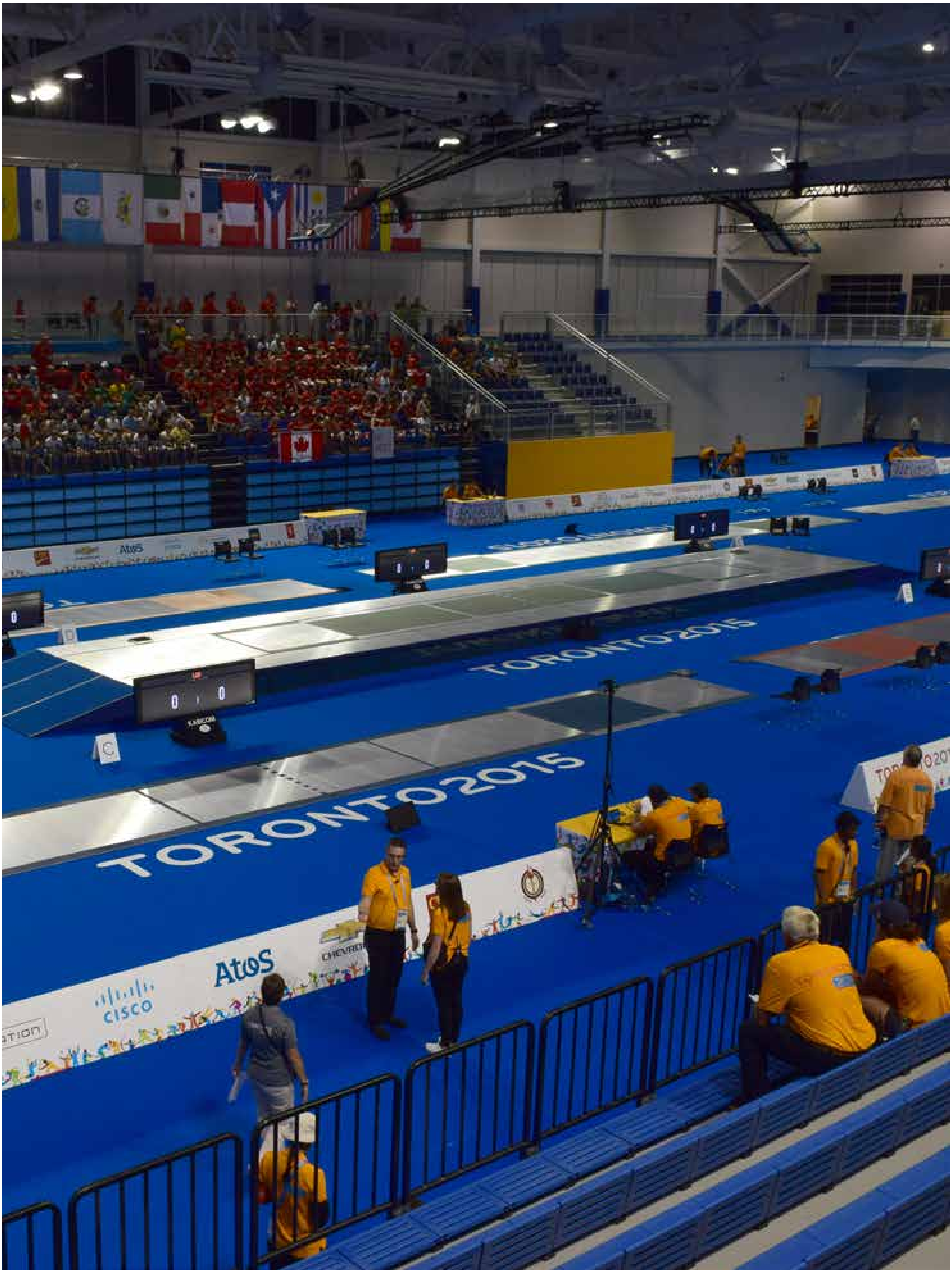


Figure 12. Network of Networks – Location of Ontario-wide observations from GRCA (magenta), TRCA (green), OMNRF (yellow), as of July 10, 2015.

5.8.3 NETWORK OF NETWORKS

Network of Networks (NoN) is a voluntary, collaborative and multi-participant program initiated by ECCC that enables all participants to share their observational data and products. The NoN program aims to enhance access, interoperability and quality of hydro-meteorological data in Canada for the benefit of all users. As part of this initiative, ECCC established a "data-sharing agreement" via a Memorandum of Understanding (MoU) with the Grand River Conservation Authority (GRCA), Toronto and Region Conservation Authority (TRCA), the Ontario Ministry of Transportation (MTO), and the Ontario Ministry of Natural Resources and Forestry (OMNRF). At the time of signing, this agreement granted access to more than 70 additional weather monitoring platforms of varying configurations. The increased density of stations reporting precipitation data is of particular use during periods of prolonged or heavy rainfall that can lead to flooding.

This "data-sharing agreement" granted ECCC access and permission to use the observational weather data provided by the GRCA, TRCA, MTO and OMNRF in support of ECCC's commitment to provide weather warning and forecast support to the Games. This data was made available to ECCC forecasters, weather briefers and scientists for use in the standard operations and Games alerting programs, validation of numerical weather prediction models, and validation and development of CaPA (Canadian Precipitation Analysis) products.



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6 INFORMATION TECHNOLOGY

From an Information Technology (IT) perspective, the Games represented an opportunity to showcase the enhanced software and systems developed over the past few years within ECCC to create and manage meteorological data and products. The challenges to support the Games were enormous; namely, greatly increasing the number of observations being collected and processed in the region of the Games (i.e., close to 60 new atmospheric monitoring stations reporting every minute), creating weather forecasts and alerts for new locations, and supporting forecaster workstations located internally and externally at the MOC and UCC.

The approach was simple: reuse and enhance existing systems. Current systems were reconfigured in innovative ways. This was combined with the addition of a few carefully selected new technologies to meet the unique operating requirements of the Games while still managing risk.

Existing Integrated Forecaster Workstations (IFWs) were designed, modified, built and supported for use by the operational forecasters, weather briefing teams and research scientists in the OSPC. The Integrated Showcase Workstation (ISW) was used by the forecasters to produce venue-specific forecasts and alerts while the briefers at the MOC and UCC used an Integrated Pan Am Workstation (IPAW). Integrated Research Workstations (IRWs) were used at the two Research Support Desks in the OSPC for real-time scientific support to operations. The IFW would have been used as a contingency should the IPAW have failed.

6.1 CREATION OF NEW INTEGRATED WORKSTATIONS FOR THE GAMES

The requirement to have fully functional forecaster workstations operating at the OSPC, TO2015 MOC, UCC and in the Storm Prediction Centre contingency office in Winnipeg, Manitoba, represented a significant challenge. It involved the following considerations:

- Moving large volumes of specialized meteorological data within and outside our internal networks;
- Reconfiguring the forecaster workstation to operate as a single unified entity rather than the client/server architecture used internally; and
- Meeting ECCC's security requirements and those of the external organizations.

To meet this challenge, the IT team modified the existing operational forecaster workstation, IFW, to create three different workstations: ISW, IPAW and IRW. All of the modified workstations featured enhancements to hardware including additional memory and replacement of standard hard drives with state-of-the-art high-speed solid-state drives. In addition, the client and server portions of the forecasting application were combined onto a single workstation and a virtual machine was introduced for further flexibility. The net result was a series of workstations that were reliable and performed significantly better than a traditional workstation by enabling local storage of data.

In addressing the challenge of moving data from within ECCC's systems to external offices, a new approach was taken. Traditionally, data is *pushed* from servers to client systems. This was not possible due to the security restrictions of the hosting organizations. To resolve this problem an enhanced client-driven *pull* data movement technique was implemented that used standard Web protocol technology as well as a messaging protocol borrowed from stock trading systems known as "AMQP."

The net result of this implementation was that all internal forecast information was made available in real time and with enhanced performance characteristics to the weather briefers operating the IPAWs at the MOC and UCC. In addition, AMQP allowed the client to configure and manage the data being viewed. Data access was strictly limited to the viewing needs as documented by clients. For any bandwidth issues, the amount of data transmitted could be reconfigured, thus allowing for successful transmission of the most important data without either overloading the system or compromising the timeliness of data delivery.

One key requirement was the capability to provide forecasts and alerts tailored to each sporting venue. In addressing this requirement, the recently implemented warning systems were reconfigured. This demonstrated the value and benefit of the recent investments in renewing our warning production systems. Also, as the format of the data in the new system was XML, it allowed for the data to be shared with our suite of partners, easily allowing them to work in parallel to meet tight and inflexible deadlines.

6.2 PRODUCTION AND CAPTURE OF MINUTELY DATA

The capture and processing of minutely observation data represented a significant test of established data management capabilities. The many challenges included how to collect, process and represent this data to each client in a manner to which they were accustomed.

In implementing the solution, a new data collection mechanism was deployed. Instead of dialing via traditional telephone modems to remote observation sites, wireless cellular modems were used, and the data was sent via the Internet to our systems.

From a data processing perspective, some key decisions were made. In order to manage workload and reduce risk, a decision was made that the output for each minutely observation would be in the same format as the data the forecaster traditionally saw at the top of the hour. While this represented a data assimilation challenge, it allowed IT experts to reuse existing software for formulas.

Requirements were gathered and specifications documented for the development of software to decode weather reports that were transmitted every minute, sent in new formats and included additional data elements from new sensors. Data elements needed to be derived that were not previously produced by ECCC, such as black globe temperature used in the evaluation of heat stress. All the decoded data, derivations and disseminated products were thoroughly documented and validated to ensure they met specifications and could be signed off well before the commencement of the Games.

To address these increased demands, computational capacity was increased by 25% and special arrangements were made to manage backlog processing if necessary. The net result of these changes was a successful solution that allowed IT experts to process and create all derived products within ten seconds of receiving an observation.

The IPAW design proved robust and flexible. When an additional and unplanned request to set up another remote office at the UCC became a requirement, it was solved simply by recreating another instance of an IPAW and deploying it.

7 INTEGRATION TESTS AND CONTINGENCY PLANS

Leading up to the Games, a significant amount of testing was required to ascertain that operational software and hardware were installed and fully functional and that the Mesonet data was available to forecasters for their analysis and interpretation. Forecasters and briefers needed to be trained on the services required of them during the Games. Their training sessions would also include information on new hardware and software, atmospheric monitoring Mesonet datasets and high-resolution numerical weather prediction and air quality model products that would be available to support the Games alerting program. The final lead-up year marked a substantial number of innovations and documented procedures to allow the teams to have both equipment and staff in place and fully operational to meet expectations. This included contingency planning to determine and document alternate courses of action for the provision of services in the event of an outage of the OSPC or either of the two briefing units.

7.1 INTENSIVE OPERATING PERIOD AND INTEGRATION TESTING

The concept of an Intensive Operating Period (IOP) was to run the "forecast, alerting and monitoring systems" from end to end just prior to and during the Games with integrated testing periods scheduled and planned as part of the process leading up to the Games. The testing would verify and validate that all instruments, workstations, forecasting work processes and staff were ready for operations. Although there was always a requirement to perform end-to-end testing and to test a new contingency plan, the IOP idea was conceived by the Chair of the Steering Committee in the fall of 2014, who asked that intensive testing be conducted over a period of time in preparation for the Games. The plan was endorsed by all of the Project's Working Groups, and by October 2014, by the Steering Committee as well. What was special about the IOP was that the scope of the testing extended beyond the operational components of the forecasting services to include the offsite briefing offices. The IOP component was not part of the original Treasury Board Submission but became an integral part of ECCC's implementation plan.

When the IOP test planning was being integrated into the overall implementation plan, it became obvious that all testing could not begin immediately as conceived, as there were critical IT systems upgrades that were required to have our Integrated Workstations operationally ready for the Games. There were also monitoring instruments and equipment that needed to be brought online. Thus, a staged approach was initiated so that over time, from the fall of 2014 to the start of the Pan Am Torch Relay in May 2015, testing and certification would be a phased part of our work and implementation. These phases were called "Integration Tests" and were the lead up to the start of the actual Intensive Operations that began one week before the start of the Pan Am Games.

7.1.1 INTEGRATION DETAILS

The purpose of the Integration Tests was to conduct end-to-end testing of operations (i.e., testing of the various components of the complex systems, identifying any gaps and correcting them). In the lead up to final readiness and operations during the Games, five Integration Tests took place approximately one month apart from November 2014 to April 2015. Integration Tests validated the following components of the IOP: People/Training/Contingency; Monitoring/Data Flow; Tools; Prediction/Production; Dissemination; Science; and Project Management Activities where appropriate. The integrations were successive and progressively elaborated with increasing scope, and each primarily focused on one or two major themes.

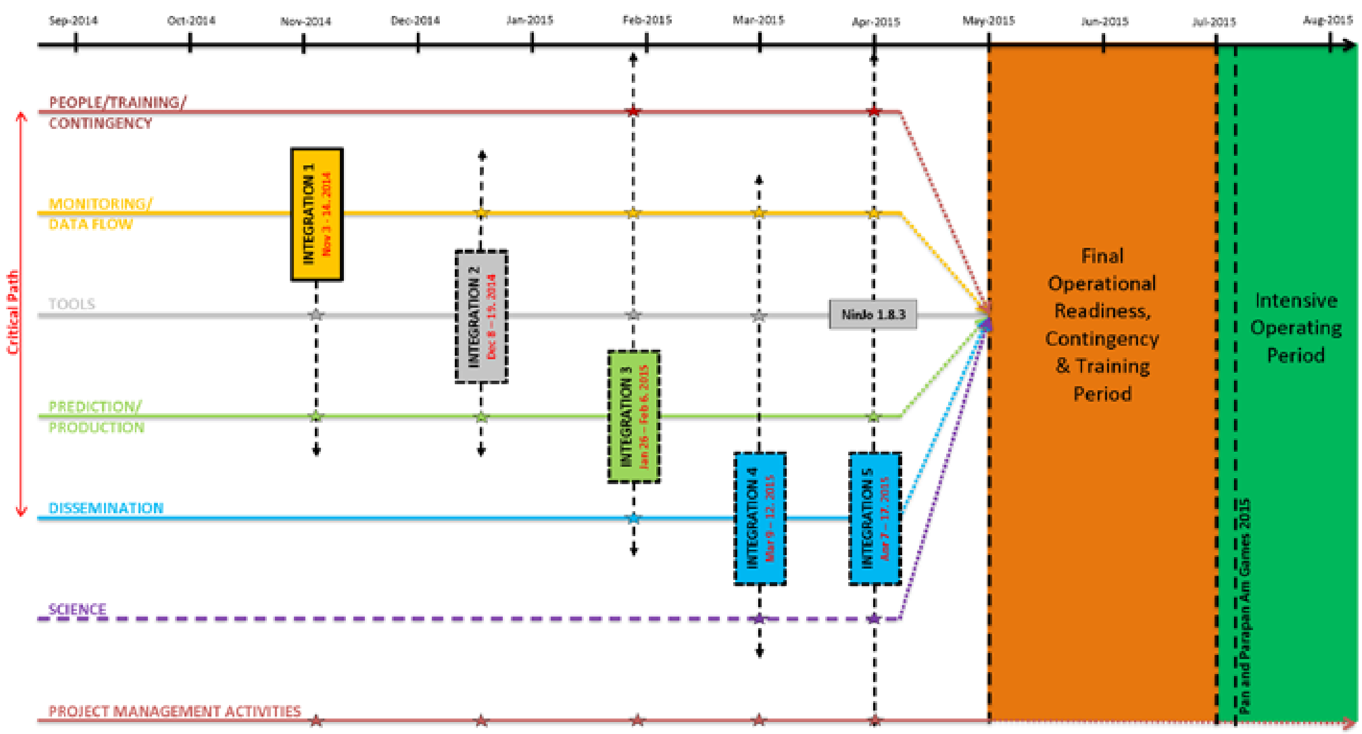

Figure 13. ECCC's Intensive Operating Period Plan.

The information below explains in some detail what was covered during each integration testing period. The integration steps have been colour coded to match the diagram that follows showing the correlation and progression of the Integration Tests.

INTEGRATION 1 – Testing focused on the basic hardware and software functionality of the ISW, observational data being delivered to this system including data from the Mesonet, as well as the capability to issue venue forecasts and alerts.

INTEGRATION 2 – The testing focus was similar to the scope of Integration 1, but included testing of two ISWs installed in the OSPC, the A-B switch (i.e., the "switch" allowed a forecaster to change from the ISW to the IFW) and forecast production software.

INTEGRATION 3 – Testing continued on the ISW in the OSPC. In addition, initial testing of an ISW in the Winnipeg Storm Prediction Centre Contingency Office, and the IPAW.

INTEGRATION 4 – Testing continued on the ISW in the OSPC and the IPAW and briefer/forecaster tools outside of the ECCC network. New testing focused on venue alerts being transmitted to EC Alert Me (see Section 9.6) and their availability to the briefers, the IRW and ECPASS (see Section 11.10).

INTEGRATION 5 – Testing simulated, as much as possible, end-to-end operations (i.e., as it would be during the Games). In addition, it included user acceptance testing before final operational readiness, contingency and training.

7.1.2 RESULTS

Documentation for each integration testing period included: a detailed plan; verification of test setup checklist; testing matrix; test cases; and a summary report. Gaps/Risks were tracked from each integration testing period and addressed during subsequent Integration Tests.

Based on the scope of the five integrations and their results, the Integration Tests were deemed successful. In summary, integration testing involved validating data flow to the ISW and IPAW (inside the ECCC network) on a staging environment inside the ECCC network. The ISW, IPAW and IRW hardware and software were proven to be robust. The processes for issuing and disseminating venue forecast and alerts were successful. The integration testing ultimately prepared Operations for the Final Operational Readiness, Contingency & Training Period (May 1–July 5) and Intensive Operations (July 6–August 15).

7.2 TRAINING

Training was a critical preparatory step towards Games operations. There was a need to identify the differences between what was considered to be standard operating procedures and generation of products and what was required for the purposes of the Games. New processes, such as the issuance of venue-specific alerts and forecasts within existing public forecast areas, required a review of product distribution applications. Trainers mitigated another potential risk by travelling to the contingency offices to provide the same training to forecasters who could be handed operational reins should any emergency situation arise requiring the shutdown of the OSPC (see Section 7.3). A new level of close coordination between forecast and briefing teams was also necessary. The teams were trained in the use of Mesonet observations, new display applications arising from this Mesonet and high-resolution experimental numerical weather products. Innovative technologies were deployed, including Doppler LiDAR instruments, mobile car top weather stations and a sensor array for a three-dimensional (3D) total lightning solution. These all required training for interpretation. Briefing teams located at the MOC and the UCC were tasked with training and/or interpreting these data and products for outside clients.

7.3 CONTINGENCY PLANNING

Contingency planning was a significant component of the preparation leading up to the Games. There had to be a plan if an emergency resulted in the partial or full shutdown of the OSPC. If forecasts and/or alerts could not be produced by the OSPC, then contingencies would transfer operations to other Storm Prediction Centres in Canada. These contingencies are in addition to the normal operations of the MSC and its Storm Prediction Centres. As a contingency, the Storm Prediction Centre in Montréal, Quebec, was designated as the backup for the OSPC for marine forecasting and alerting programs, including production of the nearshore forecasts and alerts required for the Games.

In the event of a shut-down of the OSPC, the Prairie and Arctic Storm Prediction Centre (PASPC) in Winnipeg would operate the normal Ontario operations forecast and alerting program and assume the special requirements of the Games. The office was outfitted with a dedicated IPAW configured to view Ontario data and issue Ontario forecasts and alerts. If the outage in the OSPC operations was lengthy, forecasters would be transferred from the Toronto Office to Winnipeg and flown home once the situation in Ontario had returned to normal and was deemed to be stable.

The PASPC has two offices, one in Winnipeg and the other in Edmonton, Alberta. As part of the MSC's normal contingency operations, the Winnipeg office backs up the OSPC while the Edmonton office backs up Winnipeg and is a second backup for the OSPC. In a sense, there was a double redundancy for the issuance of meteorological products and services for the 2015 Games.

Specific training was developed and delivered to train meteorologists in the contingency offices, in the event that the forecast and alerting program for the Games was transferred to their offices.

This contingency system is designed to be seamless, such that no one would notice that there was a disruption in service. This contingency operates 24/7/365, and fortunately, these detailed contingencies were never executed, though they were tested up to but not including flying forecasters out to Winnipeg. The testing included transferring systems across to the Winnipeg and Montréal offices, and the transition was seamless. It was equally smooth to have operations revert back to the OSPC once the testing was completed and deemed successful. The timing of the transition and the efficiency of it made for an effective test of the contingency plan for both the Games and for normal operations testing as well.

7.4 EMERGENCY PREPAREDNESS

Over a year and a half prior to the Games, the Project Teams planned and prepared for the possibility of emergencies that could affect their operations during the Games. It was imperative that intricate testing be undertaken in a variety of formats to ensure that both staff and systems were operationally ready for the Games. These formats ranged from planning and running ECCC's table top exercises to participating in table top exercises by other organizations. It included contingency testing, integration testing, systems tests and preparing staff. As our services were deemed to be mission-critical to the Games, there was a requirement for them to be available 24/7.

7.4.1 TABLE TOP EXERCISE – SCENARIO TESTING

In May 2014, under the leadership of the Implementation Team, ECCC invited representatives from Shared Services Canada, Public Safety Canada, Health Canada, the provincial Ministry of Health and Long Term Care, and the TO2015 organizing team to attend a table top exercise. The purpose of the exercise was to prepare ECCC and its partners for any eventualities that could, if they occurred, inhibit or impair the operation of the Project's mission. This exercise was the first step of many to review and examine the risks and vulnerabilities associated with the operations and set-up of the Project in support of the Games. There was specific focus on the incident and command structure of the Project, and the effectiveness and efficiency of the communications in each scenario was examined. In particular, the notification and escalation procedures were key components.

There were three scenarios tested for this full-day exercise. The first was a scenario where a severe storm damaged some atmospheric monitoring equipment in the Mesonet, resulting in data outage and requiring repair. The objective of this exercise was to determine the time it would take for the weather watch and weather warning to impact decisions at the MOC and to determine the time to repair the damaged equipment. In the second scenario, a sudden IT outage affected the OSPC and required the forecast operations to be transferred to the Winnipeg Storm Prediction Centre. This scenario required Shared Services Canada to quickly diagnose and resolve the outage with minimal downtime. The objective was to maintain seamless service delivery to the TO2015 client while information would continue to flow to the briefers through the Winnipeg office, rather than the normal route from the OSPC. Once the IT service was restored, the transfer back to operations in Ontario was expected to be seamless as well. The third and final scenario tested the operations of service delivery to the client in the event of a communications outage between the briefers and the OSPC. In this case, the briefers would have to work with the latest information that was available to them and to find ways of continuing to receive that information in the event that they were cut off from communications due to external infrastructure failings (i.e., within the City of Toronto) and not from within our own network. There was a measure for the diagnosis time as well as for the development of contingency planning for this type of high-impact but low-probability situation. This exercise was developed to test multiple levels of failure and increased in complexity as the situation unfolded. Although the scenario was considered to be highly unlikely, it did allow all participants to consider future contingency plans in a different light.

The overall findings of the table top exercise clearly demonstrated ECCC's level of preparedness and excellence with regard to dealing with emergencies and outages as a result of its normal course of business. ECCC has experience with alerting, notifying the public, escalating issues and resuming business quickly upon resolving failures, and the table top exercise showed these strengths.

The most obvious and anticipated risks relating specifically to the Games were found to be in the realm of communication linkages with our new partner organizations, learning each other's lines of business and how we should and would work together for issue resolution and escalation as required. Recommendations were made for further meetings to decide on operating and escalating procedures and to have contact information with many levels of backup should outages become complex.

7.4.2 TABLE TOP EXERCISE – ESCALATION AND NOTIFICATION

In June 2015, ECCC prepared another table top exercise solely based on Escalation and Notification procedures and the testing thereof. The purpose of the table top exercise was to prepare the ECCC for any eventualities that could, if they occurred, inhibit or impair the operation of the Project's mission. This exercise focused on the incident and command structure of the Project and examined the effectiveness and efficiency of the communications in each scenario. In particular, the notification and escalation procedures were key components. The interplay between the Ontario Storm Prediction Centre forecasters and ECCC briefers was also tested. For this exercise, the participants were internal to the Department. One invitee from Public Safety Canada helped plan the day and attended as an observer who provided valuable feedback at the end of the day.

Similar scenarios were run in comparison to the table top exercise the year before. This time, the focus was much more on the communication between the OSPC and the briefers, and on how the briefers would present the information to their respective clients. It was imperative for the forecasters to know that they were no longer the final providers of products and services and that the two briefing teams would tailor the information to client-specific needs.

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Figure 14. ECCC's table top exercise for escalation and notification: June 12, 2015.

The findings of this exercise demonstrated that there was substantial improvement from the previous table top exercise the year before. The scenarios ran more smoothly, with individuals having a clearer picture of with whom they would communicate and what they would be required to say. Partners were more closely engaged by this point, and the risks that were identified the year before with regard to communication issues between ECCC and its partner and client organizations were mitigated by having closer contact with all of them.

7.4.3 PROVINCIAL EMERGENCY PREPAREDNESS EXERCISE

As the provincial Government of Ontario was the official lead for safety and security for the Games, they were also responsible for preparatory exercises to test supporting federal, provincial and municipal governments along with the TO2015 organizing team. ECCC participated as the federal lead responsible for environmental emergencies. For three days in April 2015, the network of participants and players operated as though the scenarios in the script were real. The "injections," as they are called, were arriving in what would be perceived as real time, and the PEOC played a central role in coordinating responses as quickly as organizations were able to determine their course of action.

The final report prepared by the province indicated that the complexities of these situations increased with the number of organizations required to resolve them. In every case, the issues and problems were resolved, with leadership coming from the appropriate organizations that engaged and mobilized appropriate partners.

7.4.4 FEDERAL TABLE TOP EXERCISE

In June 2015, the federal departments that had a role in the safety and security of the Games participated in a half-day table top exercise led by Public Safety Canada. A few high-impact scenarios had been selected for the exercise as situations that could potentially occur during the Games. These were discussed with each of the departmental representatives sharing their state of readiness in response to each scenario. This was an informal way of verifying and validating that each federal entity was ready for situations that would have impacts across departments. The organizations were being tested for their nimbleness, their ability to discover the complexities within a problem and their ability to engage with other organizations to resolve the situation. In addition, awareness was raised of the importance to communicate with the Government Operations Centre in Ottawa, Ontario, in order to co-facilitate the engagement of key departments and organizations in an attempt to mobilize the right resources to eliminate the problem and return operations to normal.

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8 FORECAST SERVICES AND PREDICTION

This section describes the forecasting and modelling at the heart of the operation of ECCC's services in support of the Games. The modelling and prediction is a culmination of all of the foundational work that took place with the installation of the Mesonet and its associated technological infrastructure. With data flowing from instruments and equipment, the most significant piece then became prediction of daily weather conditions for each of the venues during the Games. The role and setup of the OSPC are described along with the products and services provided from within. The intricacies of various modelling tools are examined in sections 8.5.1 to 8.5.3.

8.1 THE ROLE OF THE ONTARIO STORM PREDICTION CENTRE IN SUPPORT OF THE GAMES

The Ontario Storm Prediction Centre (OSPC) is an ECCC weather forecast office based in Toronto that produces forecast products for all of Ontario, the National Capital Region, the Great Lakes and the Ontario portion of the St. Lawrence River. It is a 24/7 operation, staffed by a team of about 30 meteorologists.

In everyday operations, the OSPC produces weather forecasts (regularly issued forecasts and special alerts, including weather watches, warnings and advisories) for the general public and marine communities in Ontario. It also provides weather information and support to a variety of governmental agencies and emergency management organizations.

The OSPC provided specialized weather forecast products in support of the Games, starting with the Pan Am torch relay run prior to the Games and ending with the closing ceremonies of the Parapan Am Games. A new point forecasting methodology was used to produce venue- (or venue cluster) specific alerts and forecasts. These products and a daily Thunderstorm Outlook graphic product were provided by the OSPC starting on July 6 and continuing throughout the Games. Additionally, route-specific forecasts were produced during torch relays that preceded both the Pan and Parapan American Games.

The objective with ECCC's point forecasting methodology was to use the Mesonet in the Games footprint to provide venue-specific forecasts and alerts to our partners that could be used in decision making for Games operations. For example, if showers or thunderstorms were entering the region from northwest to southeast, the objective was to offer as much notification as possible of the impending precipitation and storm, and to identify which venues, if any, could be affected or if the storm would miss the location. This was especially important for outdoor venues. Organizers would then have the necessary weather information for Games operations and scheduling decisions, which would ultimately benefit the athletes, organizers' schedules and live media coverage of the events.

To support the program, two forecast production desks were created in the OSPC that were dedicated to Games forecasting, requiring eight full-time meteorologists. These forecasters were drawn from within the OSPC, the PASPC in Winnipeg, Manitoba, the National Lab for Nowcasting and Remote Sensing, and from the Workstation Development and Innovation team. The forecast team relied on the expanded Mesonet of weather observations, high-resolution weather forecast model data produced especially for the Games, enhancements made to the regular forecast production software tools (i.e., “NinJo” and “SCRIBE”) in order to produce the venue alerts and forecasts, and a specially configured computer workstation, ISW.

In order to disseminate the forecast products to the end users, a number of platforms were created (including the Ocean Networks Weather Portal [see Section 9.5], EC Alert Me [see Section 9.6] and the Web-based "Datamart" [http://dd.weather.gc.ca]). However, the meteorologists relied on the ECCC weather briefers at the MOC and the UCC to disseminate and provide interpretation of their forecast products to the most critical users (see sections 9.1 and 9.4).

Below are further details on OSPC operations, including the high-resolution weather models and tools used to create the specialized forecasts produced for the Games.

8.2 ONTARIO STORM PREDICTION CENTRE OPERATIONS FOR THE 2015 GAMES

The OSPC was expanded to include an additional four desks (the "quad"), two of which were Research Support Desks (RSDs), staffed by ECCC's research meteorologists (see Section 11.9 for further detail). The other two desks were staffed by meteorologists dedicated to producing the Games-specific forecast products, and providing weather information and support for Games-related activities.

The "quad" desks were physically arranged so that they facilitated easy communication and information sharing between the Games forecasters and the research meteorologists at the RSDs. Furthermore, the desks were adjacent to the main OSPC forecast desks and thus allowed for quick collaboration, coordination and consultation with those meteorologists.

Each of the operational desks was equipped with an ISW that allowed the meteorologists to access the Mesonet's observation data, output from the specialized high-resolution weather and air quality prediction models, and the specially configured Games forecast production software. Additionally, a large monitoring screen was mounted above the Games quad, to provide situational awareness information to the forecasters.

Long-standing working relationships with the United States National Weather Service (NWS) were renewed and strengthened as three staff rotated visits to the OSPC during the Games. This was for the purposes of observation and information sharing, which greatly benefited both organizations.

8.3 VENUE-SPECIFIC FORECASTING AND ALERTS

Venue-specific forecasts were issued three times per day (amended as conditions warranted) and were valid for seven days. The forecasts included sky condition, precipitation, temperature, humidity, wind speed and direction, and obstructions to visibility. The Games marine forecast for the sailing venue in Toronto Harbour was issued three times per day during the Pan Am Games (no marine forecasts were required during the Parapan Am Games). Forecasts of wind speed and direction, wave height, obstructions to visibility and precipitation were valid for five days. Neither the venue-specific public forecasts nor the marine forecast used sport-specific alerting criteria. Alerts were issued as required and were based on existing and approved ECCC criteria. Alert types included: fog advisories, heat warnings, rainfall warnings, severe thunderstorm watches and warnings, smog and air health advisories, tornado watches and warnings, generic weather advisory warnings, wind warnings, and special weather statements.

In terms of alert types, alert criteria and target lead times, the program mirrored that of ECCC's regular summer season public alerting program for southern Ontario. The differences, as with the regular forecast products, were that the Games alerts were issued for specific venue locations rather than larger regional areas, and the electronic distribution of the alert products was limited to specific decision-makers and emergency managers/responders associated directly with the Games (e.g., TO2015, sports organizations, UCC).

8.4 TORCH RELAY FORECASTS

The Pan Am Torch Relay commenced May 30, 2015, in Toronto, travelled across the country and concluded in Toronto on July 10 at the Pan Am opening ceremonies. A five-day Parapan Torch Relay started on August 3 in Ottawa and Niagara Falls, Ontario (two torches), crossed Ontario and ended in Toronto with a joint lighting of the cauldron during the Parapan opening ceremony on August 7. The Pan Am torch run required forecast and alerting support from multiple forecasts offices in the country, while the OSPC was the sole forecast source for the Parapan Torch Relay. For both relays, a three-day forecast was provided to the TO2015 Torch Relay team for locations along the torch route. In addition to a text forecast of sky condition, precipitation, maximum temperature, wind speed and direction, and obstruction to visibility, the forecast also highlighted any significant risks and potential impacts that the weather might have on the relays and associated ceremonies. Torch relay officials also had access to telephone consultations with the OSPC meteorologists as required.

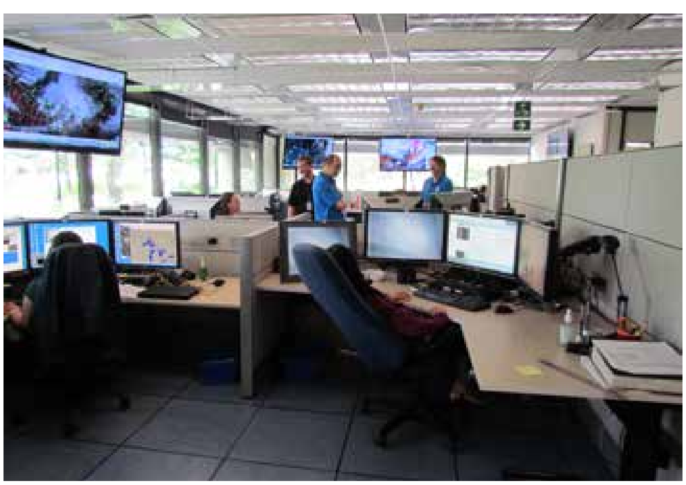

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Figure 15. ECCC forecasters at the Ontario Storm Prediction Centre.

8.5 WEATHER, WAVE AND AIR QUALITY PREDICTION MODELLING

The next subsections describe the three types of experimental prediction models that were used extensively during the Games. The first describes the high-resolution urban-scale weather prediction model, which led to a clearer visualization of meteorological features in and around the City of Toronto. The second describes the high-resolution wave modelling that took place for Lake Ontario, which produced higher wave model resolution and more accurate representation of significant wave information, especially in near-shore areas. Finally, the last subsection describes the high-resolution air quality model. This model not only provided predictions for future air quality, but also enabled a visualization of air pollution, to better understand urban pollutant sources that impact on the health of surrounding communities.

8.5.1 HIGH-RESOLUTION URBAN SCALE WEATHER PREDICTION MODEL

Numerical weather prediction (NWP) is an important tool for operational weather forecasting. The NWP systems currently used operationally at ECCC have grid spacing on the order of 10 to 50 km. Higher horizontal resolution (i.e., smaller grid spacing) is required for improved representation of critical physical processes occurring at the surface and in different levels of the atmosphere. This leads to a better resolution of atmospheric circulations and meteorological features such as lake breezes and urban heat islands that are directly linked with high-resolution surface features like cities. Improved detection of lake breezes can in turn improve the prediction of air quality, thunderstorms, lightning and other severe weather events such as tornadoes. Similarly, higher-resolution model predictions help to better define the urban heat island effect where city temperatures are often warmer than in surrounding rural areas. Complex cloud microphysics is also found to perform better in higher-resolution atmospheric models, with potential for improved forecast of severe precipitation events.

The Games footprint was over an area where lake breezes from the lower Great Lakes occur frequently during the summer, and the majority of the Games venues were in an urban environment. Experimental versions of ECCC's operational Global Environmental Multiscale (GEM) atmospheric model were therefore implemented as guidance for our forecasters and briefing teams during the Games. The high-resolution models were used in addition to the standard operational forecast models to support the venue-specific weather forecast and alerting program. Another primary objective in running the experimental models was to evaluate the quality of the numerical forecasts produced by finer spatial-scale versions of the operational GEM and to prepare for future operational implementations of these types of systems.

A 2.5-km GEM model, currently run 4 times per day for 48-hour forecasts at CMC, was the first experimental tool made available to forecasters during the Games. Two other versions of GEM, more experimental and run specifically for the Games, were integrated once per day for 24 hours with grid spacing of 1 km and 250 m. All these model versions feature state-of-the-art configurations of numerical, dynamical and physical processes, including complex representation of clouds, precipitation and atmospheric radiation. They are also able to directly represent the impact of urban surfaces on the atmosphere and have a better representation of land surface conditions (e.g., surface temperature, soil moisture) and water temperature over Lake Ontario. Outputs from the 1-km and 250-m experimental NWP systems were designed to enhance weather forecasts during the Games and to support applications related to weather and health services (see Section 12). In a sample 250-m Urban Scale model output graphic shown below, the Universal Thermal Climate Index (UTCI) is predicted for early afternoon on July 28, 2015. When the UTCI is above 38°C, there is very strong heat stress on the human body. Strong heat stress would be experienced with the UTCI in the range of 32°C to 38°C, and moderate heat stress in the range of 26°C to 32°C. The figure highlights that the strongest heat discomfort is over the most urbanized regions of Toronto, with the greatest heat discomfort located a few kilometres north, due to the lake breeze's northward advection of the warmest air.

Information was provided on standard meteorological variables such as temperature, winds and precipitation, but heat stress indices were also made available for health applications (e.g., Humidex, UTCI and Wet Bulb Globe Temperature [WBGT]). Most of these products were made available digitally through the CMC Datamart or visually through an experimental Web mapping service (map graphics).

Results obtained from the experimental GEM run during the Games were found to compare favourably against the GEM and other forecast model products that are currently operational at ECCC. Subjective evaluation of several case studies of strong precipitation and winds, intense heat, and lake breezes that occurred during the Games reveals a clear advantage of using high-resolution (km-scale and sub-km-scale) grid spacing. Preliminary results from a more objective approach based on the entire set of model integrations for summer 2015 already indicate a clear benefit (in a statistical manner) of using the experimental models compared with current CMC operational models.

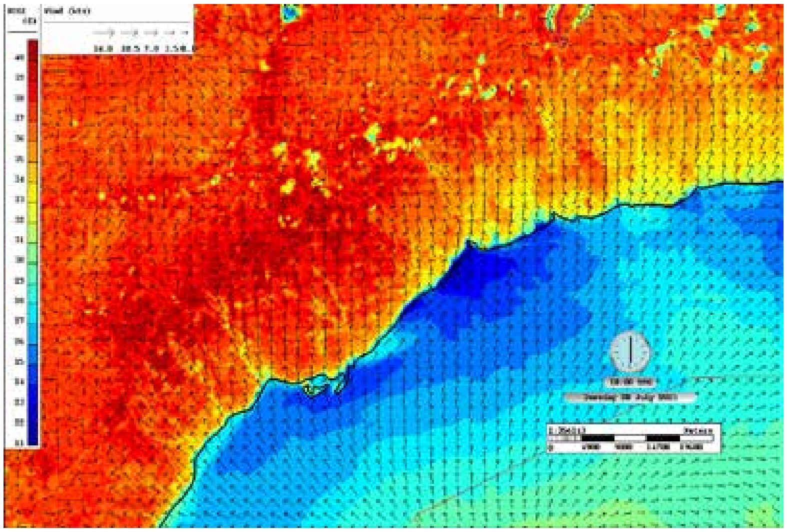

Figure 16. Model predicted fields from the Urban GEM-LAM model with 250-m grid spacing, for July 28, 2015, at 18:00 UTC (1:00 p.m. local time). Wind vectors at 10 m above canopy level (knots) are superimposed with the Universal Thermal Climate Index at 2 m above ground level (°C).

In a continuous effort to make guidance from numerical atmospheric models more accurate as well as more precise spatially, and to expand its use to a wider range of applications, the implementation of the Pan and Parapan American high-resolution GEM configurations could be considered as the basis for the next generation of CMC's short-range local forecasts. Further evaluation of the high-resolution numerical weather prediction system over the southern Ontario Games region and period will help identify and correct model weaknesses and deficiencies. Deployment of similar systems for other Canadian regions and cities is to be expected in the next two or three years.

8.5.2 LAKE ONTARIO WAVE MODELLING

During the Games, a number of open-water events were hosted in the inner harbour and south of the Toronto Islands, an area where the competition or logistics could be affected by high winds, fog, waves, severe weather or heat stress. Given these sensitivities, ECCC provided near-shore marine forecasts to inform the TO2015 Games competition management, athletes, volunteers and spectators about winds, waves and weather for the day. Wave models provide valuable guidance in the development of these forecasts. The Games gave us a unique opportunity not only to use our current wave modelling system but also to test and validate the next generation of wave forecasting systems currently under development at ECCC.

The current Great Lakes wave prediction system is a single deterministic model at 5-km resolution with 3-hourly output driven by the winds of the 10-km GEM model. Each lake is covered by its own grid, excluding Lake Michigan. An experimental high-resolution model that was tested for the Games was instructive for accelerating and informing upgrades to the Great Lakes wave modelling system. As part of the Mesonet built-in support of the Games, ECCC deployed two additional wave buoys in Lake Ontario just south of the Toronto Islands (see sections 5.4 and 5.5). Data from the buoys was used in the validation of the wave models.

Three wave modelling systems were used during the Games with horizontal grid resolution of 2.5 km, 1 km and 250 m. The deterministic wave prediction system at 250-m resolution over western Lake Ontario was deployed specifically in support of the Games. The system produced 24- hour forecasts using input from the 250-m resolution urban scale atmospheric model, described in Section 8.5.1.

The higher wave model resolution improves parameterizations, and more accurate representation of coast or shoreline leads to a better representation of significant wave information, especially in near-shore areas. In particular, the 250-m resolution grid over western Lake Ontario can begin to resolve small areas such as Toronto's Inner and Outer Harbours and realistically depict "obstacles," for example, the Port Lands and Toronto Islands, which provide a shadowing effect to waves in Humber Bay when winds are from the east. The model also allows for a detailed depiction of waves driven by features such as lake breezes and thunderstorms. An example of the effect of a fast-moving line of thunderstorms on the wave field is shown in Figure 17.

Analysis of the model performance during the Games has shown that the new wave forecasting systems performed better than the system currently in place. In particular, the 250-m resolution wave model performed the best of the three models. The OSPC forecasters also provided a positive evaluation of the new wave modelling system.

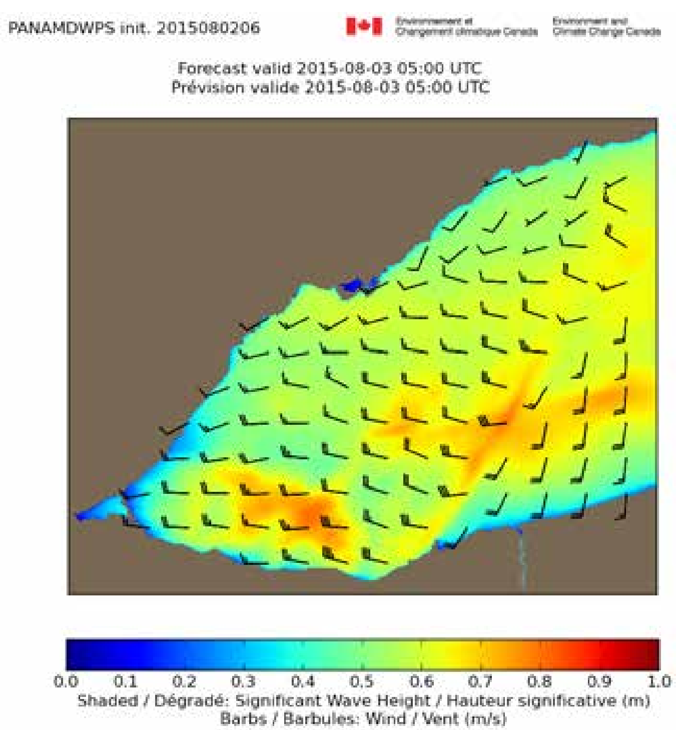

Figure 17. Simulated fields for the 250-m grid resolution WaveWatch III model forced by the winds of the Urban GEM-LAM model at the same resolution on August 3, 2015, at 05:00 UTC (1:00 a.m. local time). Significant wave height (m) and wind barbs at 10 m above surface (each full barb: 5 m/s).

8.5.3 HIGH-RESOLUTION AIR QUALITY MODELLING FOR THE GAMES DEMONSTRATION

A regional air quality model integrates our understanding of air quality by simulating pollutant emissions, chemical transformation, meteorology and deposition processes. Models not only provide predictions of future air quality, but also enable a visualization of air pollution, thus helping to interpret how urban pollutant sources are impacting the health of surrounding communities.

The Games provided an opportunity for ECCC to showcase the development and application of its next-generation air quality model, GEM-MACH, now called version 2. This also provided a unique opportunity to collaborate with other research groups within ECCC.

The Global Environmental Multiscale – Model of Atmospheric Chemistry (GEM-MACH) is the tool that combines the current state of the atmosphere and our understanding of air quality and weather to generate air quality forecasts. Forecasters use this model guidance to help them make predictions of the Air Quality Health Index (AQHI) for communities across Canada. Of great interest to CMC and the Storm Prediction Centres is the development of higher-resolution forecasts and how the predictive skill compares with the current operational model versions. The primary objective of this real-time demonstration project was to compare the performance of the 10-km grid-spaced operational GEM-MACH model (version 1.5.1) with the next-generation GEM-MACH version 2 model run at a finer grid spacing of 2.5 km.

An improved model performance of GEM-MACH version 2 would provide justification for CMC to consider future operational use of a high-resolution air quality model in highly populated urbanized areas of Canada, such as southern Ontario.

There were three main GEM-MACH version 2 development steps that were required before the Games. First, model scripts were developed with a new, more user-friendly, graphical environment to launch the model. Second, the chemistry routines from the current operational GEM-MACH needed to be ported to the high-resolution GEM-MACH, which is now based on the numerical weather prediction model GEM version 4. Prior GEM-MACH versions, including the current operational GEM-MACH, are based on the operational weather forecast GEM version 3. GEM version 4 has several advantages over GEM version 3, such as more physically based cloud physics schemes. The third development step was to create high-resolution pollutant emissions for the GTA. The spatial mapping of on-road traffic emissions, as input into the gridded air quality model, was improved by allocating emissions using the most recent Canadian road network.

The high-resolution version of the next-generation GEM-MACH model was run in real-time forecast mode from June 1 to September 20, 2015, providing 24-hour AQHI forecasts for the Games sporting venue locations. These experimental forecasts were produced once per day, in comparison with the twice per day issuance of operational model forecasts. The forecast products were placed on several data portals for dissemination. Daily forecast briefings were given by ECCC's air quality research scientists to provide guidance in selecting a daily measurement plan for the CRUISER air quality mobile laboratory (see Section 11.4). The OSPC forecasters had access to all of the operational and experimental high-resolution air quality model products for guidance in their AQHI forecasting and alerting.

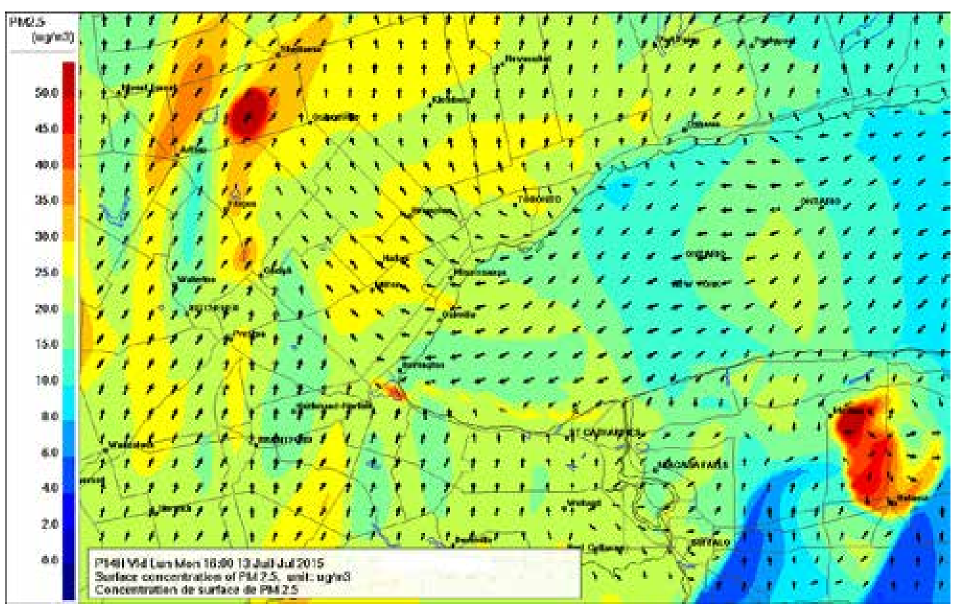

Figure 18. Model predicted $PM_{2.5}$ mass concentration for July 13, 2015, at 4:00 p.m. local time. Note the high concentration of fine particulate matter ($PM_{2.5}$) pollution predicted along the lake-breeze front over Hamilton (up to 40 μg/m^3).

Time series of real-time air quality observations for the past 24 hours and 24-hour pollutant predictions were made available to the OSPC forecasters. The real-time information was generated for observational air quality stations in the GTA, with predictions available for these locations and the Games sport venue locations. The image files from the model forecasts were uploaded to a data portal for dissemination to the wider community (OSPC forecasters, ECCC research collaborators and university researchers, Health Canada and Ontario Public Health Units). Maps of surface pollutant concentrations were also created and placed on the Science and Technology ECPASS data portal (see Section 11.10) so that outside users could manipulate the model output using Google Earth.

A suite of new graphical products and model evaluation tools were developed that can be run in near real-time to yield immediate results on model performance. The performance of the operational forecast model was compared with the high-resolution forecast model. The results demonstrated that better model performance was achieved with the new high-resolution GEM-MACH version 2, helping to identify locations and periods when poor air quality was expected.

The high-resolution GEM-MACH forecast was also sent to the University of Toronto AirSensors website (http://airsensors.ca). Through an agreement with ECCC, the University of Toronto developed miniature air quality sensors and deployed dozens of these sensors across the GTA, many near schools (see Section 12.3.3). A graphical user interface was developed to compare the GEM-MACH model results with the real-time air sensor output.

A number of air quality research projects have been developed using both the high-resolution GEM-MACH model and the special air quality observations collected by the Mesonet and by special science demonstration projects (see Section 11) in summer 2015. Two studies in particular are investigating the impacts of the urban environment and lake breezes on air quality. Asphalt surfaces in the urban environment increase surface temperatures (i.e., the urban heat island effect). Under stagnant atmospheric conditions, pollutant concentrations and circulations can be significantly altered over cities and the suburban environments. Research scientists will be studying such a case that occurred on July 28, 2015. Another study will investigate the effects of the Great Lakes lake breezes on air quality. Higher concentrations of pollutants, such as ozone (O_3), are often observed along the convergence zone of lake-breeze fronts. Lake-breeze fronts were sampled by ECCC's mobile air quality laboratory (CRUISER) (see Section 11.4) on July 24, 2015, during the Games.

An additional study and test of the model performance will investigate the impacts of urban pollution in rural communities. Urban emissions are often hot spots for air pollution, but a longer period of sustained wind from a given direction can result in rural communities being impacted by urban sources. One such case was observed during the Games on the afternoon and evening of July 13, 2015, at Parry Sound, approximately 200 km north of Toronto, when high values of O_3 were observed over several hours, as the Toronto urban pollution plume interacted with the lake breeze from Georgian Bay.

9 BRIEFING AND DISSEMINATION SERVICES

Briefing Team representatives were an important part of the new system that ECCC developed for enhanced weather monitoring and alerting services for the Games. The aim was to ensure the safety and security of Canadians and visitors from the torch relays through to the closing ceremonies.

During the Games, two teams of weather briefers were dispatched to work in two separate locations in the GTA. The first team of five briefers was located at the MOC on the Toronto lakeshore. This briefing team was ECCC's first and primary point of contact for TO2015, providing bilingual services in support of their operations for the Games. The second team with two briefers and two backup briefers was located at the UCC in Brampton, Ontario, supporting municipal, regional, provincial and federal police services in support of safety and security for the Games.

The briefing teams used products from ECCC's OSPC and data collected specifically for the Games to brief these organizations and assist in decision making as required. They were equipped with a highly customized workstation specifically designed for the Games. This workstation, and the ones used by the OSPC, also ingested weather and air quality data specifically collected for the Games from ECCC's enhanced Mesonet (see Section 5). The Mesonet provided data minutely to the briefing teams and the OSPC, an enhancement to hourly observations from the standard reporting network. The increased number of weather observations within the Games area provided a more detailed view of the state of the atmosphere during the Games. The briefing teams tailored the forecast products and observational data into relevant information that was easily interpreted by the TO2015 Games decision-makers.

9.1 BRIEFING TEAM AT THE TO2015 MAIN OPERATIONS CENTRE (MOC)

During the early discussions and meetings with TO2015 in 2012, it was identified that an MSC presence would be required at the MOC. In the spring of 2014, the briefing team's lead was recruited to coordinate this presence at the MOC, and to work with TO2015 to identify requirements and the logistical aspects of the MOC Briefing Team. The lead staffed the MOC Briefing Team with four additional briefers with strong bilingual communication skills and experience in briefing large groups and media.

There were two internal training sessions for the briefers where the scope of the training included their new tools, client requirements, contingency protocols and communication logistics. All tools that would be used by the briefers were tested by June 2015. The IPAW, their primary tool, would provide rapid access to meteorological data and information directly from ECCC's OSPC.

The hours of operation of the MOC Briefing Team were from 6:00 a.m. to 10:30 p.m. After 10:30 p.m., there was a handover to the OSPC until the MOC briefer arrived the next morning and was briefed by the OSPC. The MOC operated from 6:00 a.m. to 1:00 a.m. On a few occasions, the MOC Briefing Team extended its hours of operation in the evening due to significant weather.

There were five scheduled briefings to TO2015 per day, but this schedule varied based on client requirements. French-language weather briefings were provided on request. The first weather briefing of the day at 6:30 a.m. allowed Games management to have as much lead time and warning for impending active weather as possible so that decisions could be made, for example, for outdoor sporting event schedules and/or safety of volunteers and spectators. The MOC briefers also prepared two weather summaries each day for wider email distribution by the TO2015 organization. A large display screen was used extensively by the briefers, and very much appreciated at the MOC for a quick status update on the location of precipitation or lightning.

The MOC Briefing Team quickly adapted to any new requirements that were presented to them. The various representatives at the MOC communicated these requirements, and the Briefing Team quickly prepared for it. It became clear to the MOC briefers that they would have to deal with requests outside the primary mandate of safety and security. For example, it was learned that any wind above 50 km/h was important to venue management, while temperature exceeding 30°C triggered action from the TO2015 workforce representatives. Some venues were also very sensitive to any rain. Baseball, for example, had very specific procedures to follow, and maintenance staff at the venue had very specific requirements if any rain was forecast.

The MOC Briefing Team learned rapidly that any convective weather (i.e., showers to thunderstorms) escalated the demands on the desk beyond the capability of a single briefer. On many occasions, the desk was staffed with an additional briefer on the evening shift, and on very active convective weather days, the day shift would have as many as three briefers present during the active late afternoon hours. The ability and flexibility to overstaff proved essential to serve the client well, and also for maintaining a reasonable amount of stress and workload on the briefers.

Lightning was the largest concern to MOC and TO2015 stakeholders. MOC personnel relied heavily on the Briefing Team to monitor and alert them of lightning threats. The Briefing Team was asked to alert MOC when lightning could threaten any venue within the hour.

Overall, the MOC Briefing Team performed extremely well by demonstrating their adaptability and versatility during the Games. Almost every tool was used, and many of the planned contingencies were also used. In addition, weather products were created in anticipation of sport-specific requests. The success of the MOC Briefing Team can be attributed to the preparations conducted prior to the Games, the skills set assembled within and the willingness of each member to share his or her skills and knowledge.

Figure 19. ECCC's Briefing Team at the TO2015 Main Operations Centre.

9.2 BRIEFING TEAM AT THE UNIFIED COMMAND CENTRE

Late in the fall of 2014, the UCC leadership indicated that an MSC presence would be an asset to them, and by the spring of 2015, the MSC agreed to have a briefing team at the UCC for the Games. This late decision meant that the MSC had very limited time to assemble and train the Briefing Team and to address technological challenges, including communication and equipment acquisition.

A briefing team lead was recruited within ECCC to coordinate the UCC Briefing Team. It was determined that a briefing team of two members was required to cover the 10-hour daily shifts from 9:00 a.m. to 7:00 p.m. Two backup briefers were also recruited to ensure that a briefer would always be available. Unlike the MOC, which closed at 1:00 a.m., the UCC operated 24 hours per day. Once the briefers left for the day, the UCC received its briefings from the OSPC forecasters. For both briefing teams (MOC and UCC), briefing services were only provided during the periods of the Pan Am Games and the Parapan Am Games.

The briefers were equipped with the same tools and contingencies as the MOC briefers to support three scheduled daily briefings and any impromptu requests. The MSC UCC Briefing Team worked very well with UCC staff on shifts; it was a very positive environment and working relationship. Flexibility was also built into the UCC, so that schedule and duties could be adjusted when required by service requests.

At 5:45 a.m., the forecaster would phone the UCC duty officer's desk to provide a weather briefing for the day, which would provide enough detail and information to allow the Command Centre officers to create their situation reports and briefings for their Deputy Commissioner. Once the briefer arrived at 9:00 a.m., he or she would receive a full weather briefing from the OSPC forecaster. The briefer was then the main weather contact for the UCC officers until the end of his or her shift at 7:00 p.m. At that time, any required weather services reverted back to the night shift forecaster at the Games desk within the OSPC.

The UCC Briefing Team, like the MOC Briefing Team, was overall successful in delivering quality services to the client. Following the Games, the Federal Security Coordinator, RCMP lead, indicated that any future large events would also benefit from ECCC's presence in their Integrated Security Unit.

9.3 SUPPORT TO THE PROVINCIAL EMERGENCY OPERATIONS CENTRE

Within the PEOC, the coordination of the security risks and concerns were handled daily. Weather updates were provided to facilitate their decision making. However, there was a separate and special team identified to handle safety and security issues related only to the Games venues and operations. Each morning at 8:00 a.m., ECCC participated in the PEOC Situational Awareness conference call to discuss any outstanding issues from previous days and any risks or emerging issues for the current day or future days, which could include hazardous weather. These calls were conducted early in the day to allow partners and stakeholders to provide status updates on any issues that took place in previous days that required multiple days to resolve. Also, any anticipated threats or risks were discussed on the call, and mitigation strategies were established within the network to maintain as smooth an operation of all sporting events as possible. Weather updates were always required, and they facilitated decision making for any outdoor concerns of the day.

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Figure 20. The Hon. Elizabeth Dowdeswell, Lieutenant Governor of Ontario, visiting the briefing team at the Police Unified Command Centre.

The final integration factor where a briefing cycle played an important role was operations at the PEOC. At the PEOC, the partners for the Games were requested to participate in a daily conference call. It was an opportunity to communicate what partner support would be required to address issues and to provide a status report on anything that needed more than one day to be resolved. If required, another conference call was convened at 5:00 p.m.

9.4 SUPPORT TO ESSENTIAL FEDERAL SERVICES

ECCC's support to EFS was critical to all multi-jurisdictional services in support of the Games. One of two individuals from ECCC's Project Management team participated daily on all briefing calls related to the provision of weather services to all EFS partners. There were also scheduled briefings between this EFS briefing team and ECCC's briefers at the MOC and UCC. Multiple touchstones during each day permitted a cross-communication between the three briefing teams and the forecasters at the OSPC.

Colleagues knew and understood that calls could be convened of the federal group at any time if situations arose requiring the urgent and immediate attention of the partners. Apart from any impromptu meetings, the EFS team required from each partner an end-of-day report that was to be submitted by 6:00 p.m. This report described the day's activities and was also used as a briefing tool for the following day to ensure continuity. ECCC provided a summary of the day's weather events and its impacts on the Games. Had there been an environmental emergency, then this report would have taken on a much more descriptive tone related to the emergency and the associated environmental conditions.

9.5 THE OCEAN NETWORKS WEATHER PORTAL

Internally, the OSPC forecasters and briefing teams at the MOC and UCC had a suite of tools to view the Mesonet data and produce forecasts and alerts. Ocean Networks Canada, a not-for-profit society created by the University of Victoria in British Columbia, provided ECCC with the platform for distribution of our products to external users. This fully bilingual (English and French) weather portal delivered our surface weather observations, weather forecasts and alerts to security services, TO2015 and those sporting federations approved by the TO2015 organization. The new weather portal was a supplementary tool often used internally by forecasters, briefers and scientists.

The portal was a noted success, allowing approved users to access up-to-the-minute weather conditions for their venue while also viewing the venue-specific weather forecast and alert status. The site hosted over 900 unique users for just over 12 000 site visits, which made for a significant reduction in routine queries to the ECCC weather briefing teams.

9.6 EC ALERT ME

EC Alert Me is an email and Web service developed by ECCC for the general Emergency Management Community to deliver weather and environmental alerts to subscribers. A modified EC Alert Me service was tailored specifically for venue managers and Games planners. Subscribers would receive venue-specific alerts. The products that were made available were:

- Smog and Air Health Advisories (SAHA);
- AQHI Alerts;
- UV Alerts;
- Lightning Forecast Alerts; and
- Venue-specific Weather Alerts.

To view the alerts, an email was sent out with a link to the Web page where more details could be found depending on the alert type. The AQHI page was the one exception where most users received only an email. For specific users, approved by the Air Quality and Health program, an additional link was added to the provincial "WISDOM" Web page (see Section 12.3.1 for details on WISDOM).

In excess of 300 people subscribed to the Games-specific service in contrast to the approximate 12 000 clients using the general EC Alert Me email and Web service.

9.7 LIGHTNING ALERTING

A mobile lightning application was developed by Vaisala Canada Inc. in support of the FIFA 2015 Women's World Cup and Canadian Heritage, which provided funding for the development of the application. It proved to be so successful for FIFA that an expanded version was approved for use for the Games. The application provided updates of lightning activity from the Canadian Lightning Detection Network every 60 seconds for user-selected venues. Each update showed the past 30 minutes of actual lightning strikes with an accompanying call-to-action safety message.

Based on feedback that was received on the lightning application, the most important lesson learned was that lightning risk information should be presented in a simple and easily understood fashion, one that does not require interpretation by an "expert." In the short period of the 2015 Games, the Vaisala lightning application met this criterion.

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10 ENVIRONMENT AND CLIMATE CHANGE CANADA GAMES OPERATIONS CYCLE

As an EFS provider for the Games, it was imperative for ECCC that the forecasting and briefing teams understood their own daily schedules and deliverables as well as those of the other teams. In any given 24-hour day, each ECCC operational team was responsible for the delivery of both products and services to their respective clients. These clients had very different needs and requirements. It is important to remember that communications were never limited to just the scheduled times, particularly during days with active weather in the region, when more frequent communications were required.

Figure 21 and Figure 22 depict the Pan Am and Parapan Am Games operations cycles, respectively, for the four ECCC teams: the OSPC forecasting team (red text in the figures), the briefing team at the MOC (green text), the briefing team at the UCC (blue text) and the briefing management team for EFS (purple text).

The OSPC provided 24/7 weather services for the duration of the Games, including continuous watch during the "off-hours" of the MOC and the UCC briefing teams. The arrival and departure of briefing teams required a full and complete weather briefing between the teams and OSPC. The marine, public and AQHI forecasts regular issue times are shown on the Operations Cycle. These forecasts could be updated, and alerts issued, when required. Similarly, changing weather and forecasts could give rise to unscheduled briefings between the briefers, OSPC, MOC and UCC.

The Parapan Games Operations Cycle differed from the Pan Am Operations Cycle in that:

- No marine forecasts were issued;
- An International Parapan Committee Briefing was scheduled at 8:30 a.m.; and
- The verbal briefing to the UCC, RCMP Site Representative was scheduled for 2:30 p.m., rather than 3:45 p.m. (i.e., 14:30 and 15:45 local time).

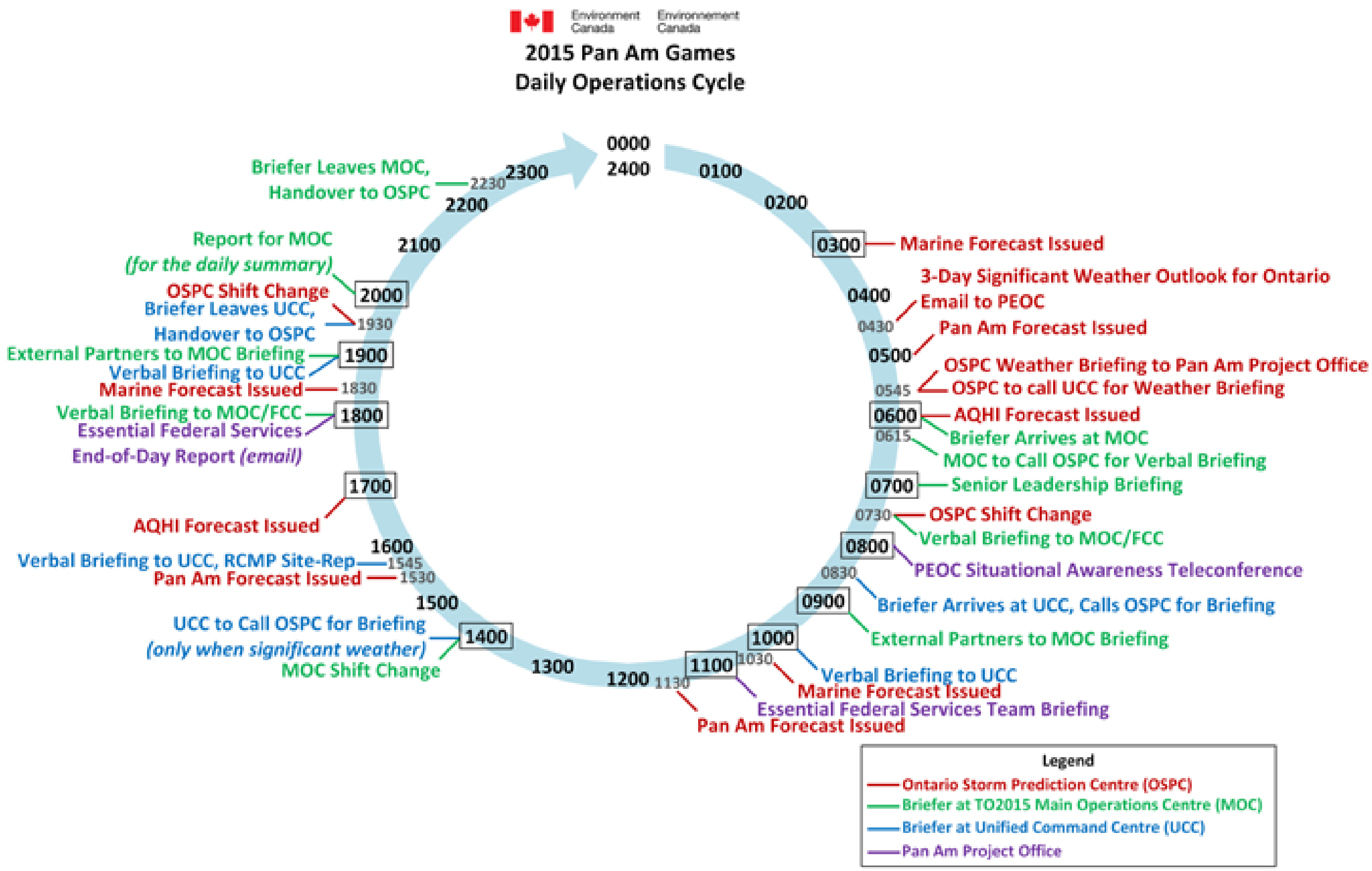


Figure 21. The ECCC Operations Cycle during the 2015 Pan Am Games.

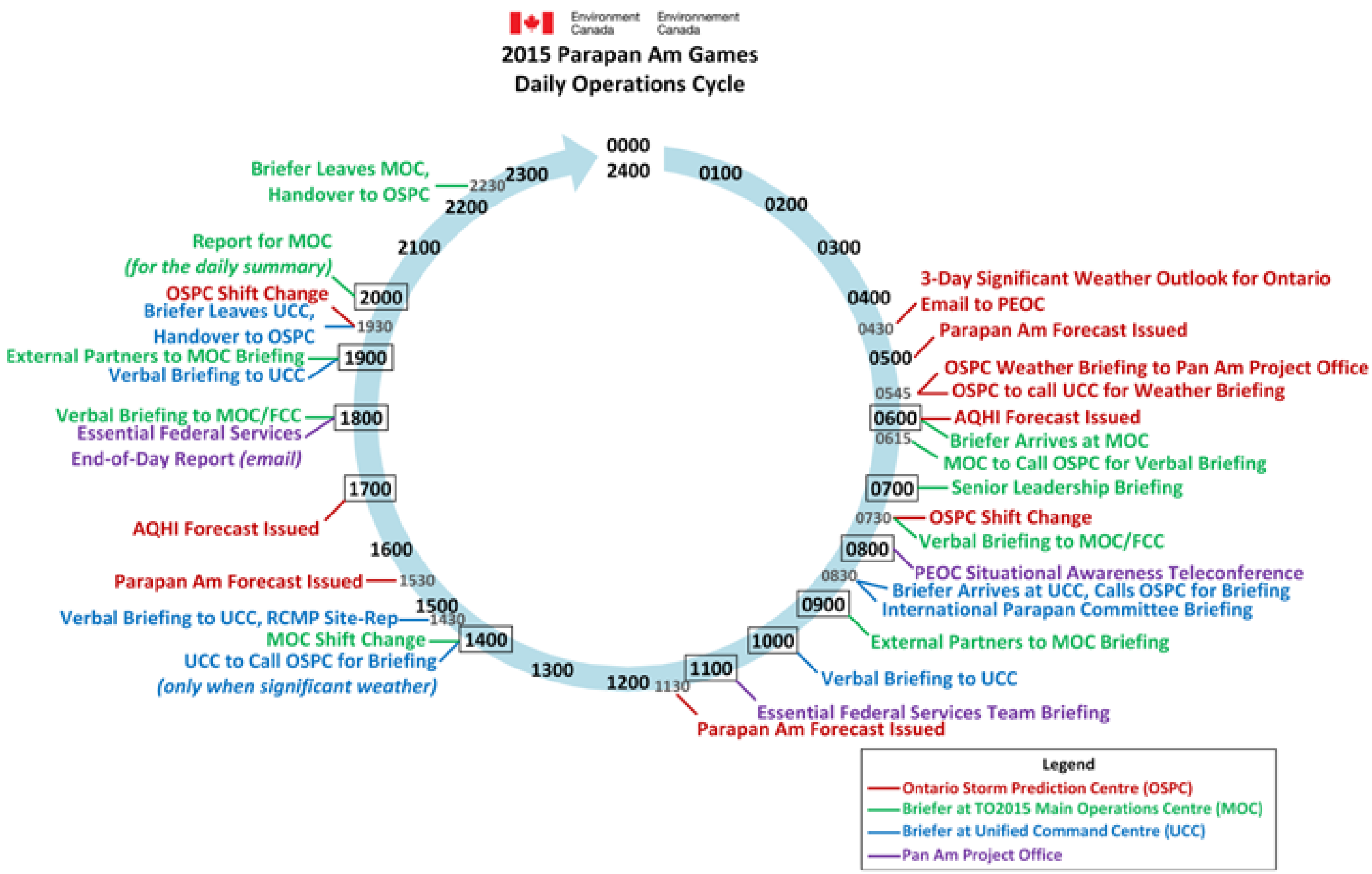
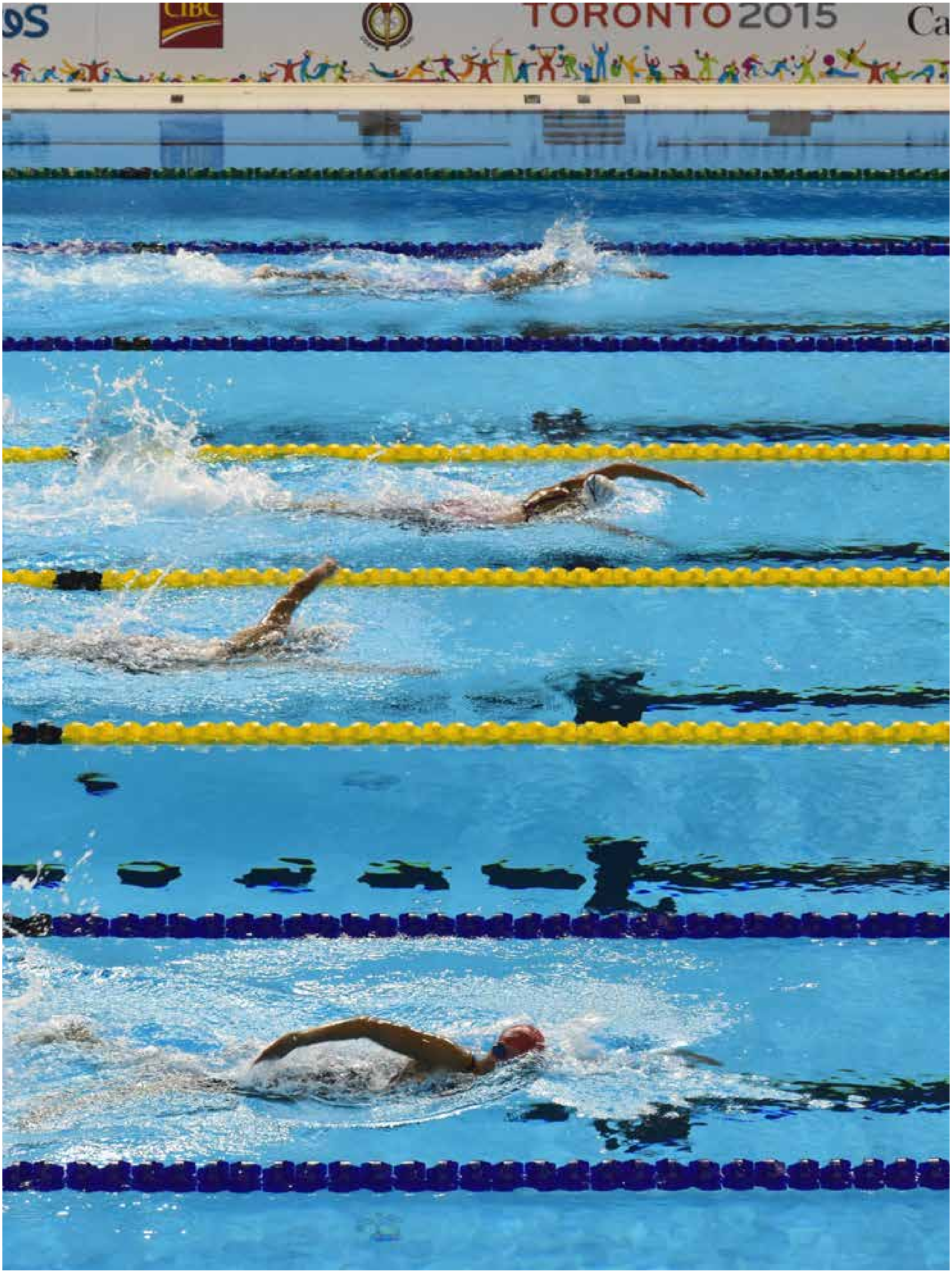


Figure 22. The ECCC Operations Cycle during the 2015 Parapan Am Games.



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11 RESEARCH

Although ECCC's mandate for the Games was to provide venue-specific forecasts and alerts, various ongoing research and development activities were aligned to take advantage of the unique opportunities provided by the Games. ECCC's research showcase for the Games leveraged our state-of-the-art science and technologies. The goal was two-fold: support ECCC's operations during the Games, and learn from the research and development to make a great meteorological service even better.

ECCC showcased a number of new technologies and instruments, which are described in the following sections. The research instrument platforms provided observations that supplemented the automated land- and marine-based Mesonet described in Section 5. All available observations were used to increase our understanding of meteorological and air quality science, particularly over an urban environment. ECCC will use this new scientific information to improve the accuracy and lead time of its alerts.

11.1 DOPPLER LIDAR

Detailed measurements of wind speed and direction are crucial for creating accurate weather forecasts. Current wind measurements use an instrument (an anemometer) to provide wind speed and direction at one location. ECCC recently acquired two remote sensing instruments, Doppler LiDAR (Light Detection and Ranging). These Doppler LiDARs are a significant improvement over anemometers, as they provide detailed measurements of the wind every 3 m along a continuous line of sight out to approximately 7 km away (depending on the weather conditions).

Doppler LiDARs are a relatively new technology that has only recently been made more affordable due to mass production techniques. The instrument uses light in the form of a pulsed laser to observe the movement of aerosols such as minute dust and other particles in the air, and to measure the direction and speed of the wind based on that movement. Near real-time observations of winds at any elevation or angle are possible using this technology, with each scan taking less than a few minutes to complete.

Two Doppler LiDARs were deployed during the Games; one at Hanlan's Point (Toronto Centre Island) and one in the back of a pickup truck, enabling it to be mobile. The main objective of the Doppler LiDARs was to provide near real-time wind data to ECCC's OSPC in order to provide wind fields for severe weather monitoring and characterization of lake-breeze fronts. Another objective was to measure winds over Lake Ontario to aid Games officials directing the sailboat events.

Two Doppler LiDARs successfully provided detailed mappings of wind speed and direction during severe weather events, improving our understanding of the convective and dynamic processes driving those events. Significant oscillations in wind speed were mapped across Lake Ontario. The mobile LiDAR mounted on a truck enabled researchers to position the LiDAR at areas of interest and take mobile measurements of convective wind fields during storms. This allowed researchers to study the evolution of the lake-breeze front uniquely and in significant detail when combined with measurements from the Atmospheric Mobile Meteorological Observational System (AMMOS) (see Section 11.2). The LiDAR mapped winds before, during and after lake-breeze formation; the mobile platform allowed researchers to relocate the LiDAR during lake-breeze events and to take measurements from multiple locations across the GTA, which were used to study the relationship between wind speed and wave forcing over the lake.

The Doppler LiDARs successfully provided near real-time data on wind speed and wind direction to ECCC's forecasters. Measurements of wind speed, direction and wind field maps were uploaded in near real-time to the RSDs for analysis by forecasters and researchers, and was available to the TO2015 event coordinators through ECPASS (see Section 11.10). Measurements from both LiDARs, which mapped out wind speed and direction over Lake Ontario and Toronto's harbour, aided in coordinating the timing and location of sailing events. These wind measurements were also useful for determining the evolution of storm systems by measuring the degree of convection (upward moving air) and the horizontal movement of air masses above the GTA; these measurements will be compared with numerical weather prediction model results and analyzed in further detail.

Analysis of lake-breeze fronts, model winds comparisons, and wind-wave relationships measured over the buoy are under way. Further evaluation of the Doppler LiDAR technology will be conducted to assess its performance in Canadian Arctic conditions. Deployment of additional Doppler LiDARs at several Arctic locations and at Toronto Pearson Airport will be completed in summer 2016.

Figure 23. ECCC Doppler LiDAR at Hanlan's Point on Toronto Centre Island.

11.2 AUTOMATED MOBILE METEOROLOGICAL OBSERVING SYSTEM

Three hybrid vehicles equipped with AMMOS units were deployed during the Games as part of the high-resolution atmospheric monitoring network, the Mesonet. AMMOS vehicles travelled routes between the Lake Ontario shore in Toronto and suburban/rural areas to the north and west. These three mobile stations collected standard meteorological data (i.e., temperature, humidity, pressure, wind speed and direction) at one-second intervals in locations where fixed stations cannot, such as along roadways surrounded by large buildings in downtown Toronto known as "urban canyons." AMMOS vehicles also carried fine particulate air quality sensors, and one AMMOS vehicle carried a prototype AirSENCE air quality sampling system (see Section 12.3.3).

The AMMOS mobile observations complemented those from the Mesonet, helped monitor weather and air quality conditions during the Games, and thoroughly sampled lake-breeze fronts for study post-Games. Three summer students and 6 ECCC scientists operated the 3 vehicles, mostly in pairs (1 student with 1 scientist). Nearly 10 000 km were travelled over 22 intensive observation days.

On July 28 and 29, 2015, some of the hottest weather of the summer provided an opportunity to make unique measurements of Toronto's urban heat island. Two AMMOS units, the CRUISER mobile air quality unit (see Section 11.4), and Western University's urban meteorology mobile unit made coordinated measurements over two periods: during peak heating on the afternoon of July 28 and during peak cooling in the early morning hours of July 29. Preliminary results suggest that some of the highest ozone (O_3) concentrations in Toronto in years were measured on the afternoon run. Temperature gradients proved equally interesting, with early morning temperatures of approximately 27°C in downtown Toronto, while outlying areas reported approximately 19°C. This unique dataset can be used to validate the performance of the high-resolution urban-scale model for this event.

AMMOS technology, as developed by ECCC, has been used in Canada and the United States since 2007 to sample severe thunderstorm and tornado environments. However, this was the first time that multiple AMMOS units had been used in a coordinated fashion in Canada, and the first time that AMMOS technology was used to gather information about heat stress and temperature in urban canyons and air quality in an urban environment, as well as to provide data in support of sporting events.

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Figure 24. The three AMMOS units installed on hybrid vehicles, with their ECCC operators.

11.3 SOUTHERN ONTARIO LIGHTNING MAPPING ARRAY

A Lightning Mapping Array allows for high-resolution 3D detection of "total lightning," meaning both cloud-to-ground and in-cloud lightning flashes. This cutting-edge technology was first implemented in the United States for lightning detection across areas with a high risk of severe thunderstorms.

The Southern Ontario Lightning Mapping Array (SOLMA), installed for the Games, was the first application of this system in Canada. It consists of 14 ground stations in the Greater Golden Horseshoe Area tied to a central computer that processes and integrates the data. SOLMA has a lightning detection efficiency of 100% within the array and has very fine temporal and spatial resolutions

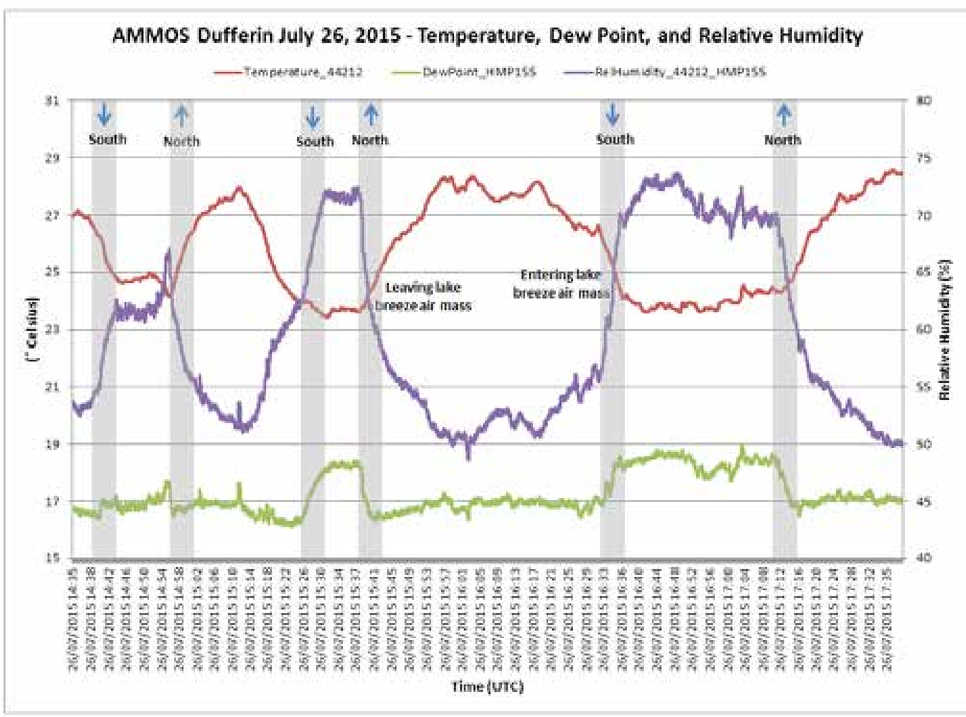

Figure 25. Temperature, dew point and relative humidity data collected by an AMMOS-equipped vehicle on 26 July 2015 as it repeatedly sampled a narrow lake-breeze front. Warm, dry air was found on the north (landward) side and cool, moist air was found on the south (lakeward) side.

(on the order of tens of nanoseconds and tens of metres, respectively). Thunderstorms were detected on 9 days during the Pan Am Games in July, and on 5 days during the Parapan Am Games in August, with strong thunderstorms on 6 of those days. These data were available to the RSDs, OSPC forecasters and the 2 briefing teams.

The SOLMA was installed primarily to investigate short-term forecasting of storm intensity, or "nowcasting." Recent studies have shown that a rapid increase in total lightning activity, termed a "lightning jump," often precedes the occurrence of severe weather. Increasing the lead time for alerts related to severe weather is therefore possible using SOLMA data.

The SOLMA data are also used to improve scientists' understanding of lightning development and evolution over the lifetime of a thunderstorm, to compare with Canadian Lightning Detection Network data, and in general to gain familiarity with the uses of total lightning. A new total lightning product will soon be available to scientists and meteorologists across Canada via the Geostationary Lightning Mapper aboard the National Oceanographic and Atmospheric Administration's (NOAA) next generation of geostationary Earth observing systems, the GOES-R satellite, scheduled to be launched in October 2016.

Figure 26 shows SOLMA data in 3D over a period of less than two seconds, with the oldest point sources coloured in blue and the newest point sources coloured in red. The sources that extend from over Lake Ontario toward land near Burlington correspond with the lightning flash in the photograph.

11.4 CRUISER AND RELATED AIR QUALITY MEASUREMENTS

Air pollution in large Canadian cities such as Toronto and the surrounding Greater Golden Horseshoe Area continues to pose risks to human health. The key pollutants used to monitor this pollution and inform the public are fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3) and nitrogen dioxide (NO_2), which are used to compute the Air Quality Health Index (AQHI). Transportation is an important source of these pollutants, including the large amount of car and truck traffic on the highways and roads, and transit hubs such as airports and rail yards, where considerable numbers of people and/or quantities of goods move through each day. Important scientific questions remain about the characteristics of the full mixture of gaseous and particulate pollutants associated with transportation emissions,

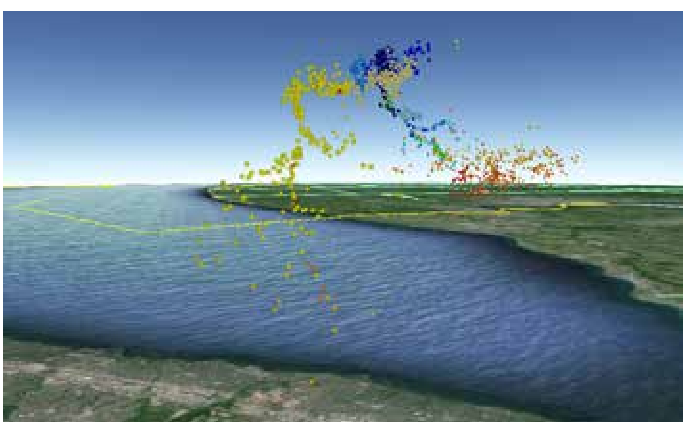

Figure 26. Images of 3D SOLMA data (left; underlying map from ©2015 Google Earth) capturing full details of lightning flash, including the parts hidden by cloud, in the early morning hours of July 18, 2015 (right: photo used with the permission of David Piano).

their correlation with variations in the AQHI across both space and time, and the influence of local weather patterns on these variations, especially lake breezes caused by Lake Ontario.

Air quality researchers deployed several new pollutant measurement technologies during the Games to address these questions. ECCC's mobile air quality laboratory (CRUISER – Canadian Regional and Urban Investigations System for Environmental Research; see Figure 27) is a specially equipped truck fitted with advanced air pollution measuring instruments. During the summer of 2015, the CRUISER was driven along various routes in the region depending upon the weather pattern. The research team also conducted unique experiments at a location adjacent to Highway 401 and in both downtown and north Toronto. A remote-sensing system was installed to measure several pollutants and atmospheric mixing along a path over Highway 401 to evaluate a new way to measure emissions. This also included highly sensitive particle detectors capable of measuring the tiniest quantities of soot coming from engines and the amount of sunlight that these particles absorbed, to better understand their impact on our climate.

The CRUISER carried the latest technology to measure NO_2, chemical components that make up $PM_{2.5}$ and gaseous pollutants, such as volatile organic compounds, that contribute to the formation of O_3 and $PM_{2.5}$ and potentially to the toxicity of the air we breathe. To date, air pollution studies have shown that the presence of Lake Ontario has a significant impact on the local weather and air quality over the greater Toronto region. The CRUISER successfully made measurements across the lake-breeze front on July 20, 24 and 28, and these data are helping to assess how well the high-resolution meteorological and air quality forecast models were able to perform. The July 28 event was also associated with a significant "urban heat island" effect, with O_3 levels exceeding 90 ppb, among the highest measurements made in recent years. On seven days, the CRUISER was driven along the remote-sensing path on Highway 401. These comparative measurements are now helping the research team assess the feasibility of longer-term remote sensing studies to better understand how much air pollution is generated from one of the busiest sections of highway in the world.

All of the data gathered on the CRUISER drives, bordered by Burlington (west), Ajax (east), Newmarket (north) and Lake Ontario (south), are being mapped to explore small-scale patterns within neighbourhoods and large-scale patterns across the entire region. This will provide the most detail ever obtained in the region, which will lead to new approaches to test and improve the air-quality prediction models and estimates of what people in this region are breathing. Ultimately, this work will support future assessments of air pollution health impacts and studies of transportation's role in air pollutant issues. Furthermore, the experience that air quality researchers obtained in deploying new measurement technologies during the Games will pay dividends to many future air pollution studies throughout Canada, including in other cities, and downwind of large resource development activities such as the oil sands.

Figure 27. ECCC's mobile air quality laboratory, CRUISER.

11.5 ULTRAVIOLET INDEX DEMONSTRATION PRODUCTS

ECCC has been providing one-day forecasts of the ultraviolet (UV) index for various locations in Canada since the early 1990s. The UV index forecasts mainly reflect the attenuation of the solar UV irradiance at solar noon by the atmospheric column ozone amount and the daytime averaged cloud opacity. The column ozone amount is first statistically estimated from weather forecast conditions, followed by an adjustment based on column ozone measurements from stations in the ECCC ozone network. The additional attenuation due to clouds is imposed through a scaling factor estimated from cloud opacity conditions.

ECCC has since implemented a chemical data assimilation system for ozone forecasting that is fully integrated into its NWP system. Ozone satellite measurements are assimilated for producing real-time ozone analyses, which serve as initial conditions for the forecasts. This coupled numerical system produces comprehensive UV index forecasts for all weather conditions, which take into account daily ozone and cloud variability.

Initial demonstration UV index forecasts from this experimental system were generated for the Games, to be validated against four additional ground-based UV radiometers (ultraviolet radiation instruments; see Section 5.6) installed across the region. The product made available during the Games consisted of hourly forecast maps of the all-sky UV index covering four days and updated daily. The clear-sky UV index and column ozone maps were also made available through the Université du Québec à Montréal (UQAM) website. These main products were produced with a resolution of 25 km, although a specialty UV index field was generated at a 10-km resolution over the Games footprint. An evaluation of the demonstration UV index is currently under way, as are evaluations for the various related products beyond the currently operational one-day forecasts.

11.6 UNMANNED AERIAL VEHICLE

The Unmanned Aerial Vehicle (UAV) used during the Games was developed for atmospheric profiling of meteorological parameters, including radiosonde or upper air observations (see Section 5.7 and Figure 28). The Atmospheric Profiling-UAV (APUAV) instruments have been developed over the last three years. The APUAV has four small propellers, is lightweight (approximately 1.5 kg) and can carry an instrument "payload" of approximately 700–800 grams. Its maximum flying height can reach 3 km. It is completely controlled by a computer system and can make flight patterns similar to aircraft manoeuvres. The main meteorological observations taken by the UAV include temperature, relative humidity, pressure, wind speed and gusts, and GPS positioning information. In addition to these measurements, there were two unique air quality probes added to measure carbon dioxide (CO_2) and the total number of aerosol concentrations.

The APUAV used during the Games was unique in the way that atmospheric profiling of meteorological parameters and aerosol observations were performed. Its measurements were found to be comparable to the observations of the PUMS (Pan Am and UOIT [University of Ontario Institute of Technology] Meteorological Supersite), which was located at the UOIT Wind Farmland Campus, east of Toronto (see Section 11.7). The observations from the APUAV can be used for numerical forecast model validations, remote sensing applications, monitoring for environmental issues, and contributing to profiling performed by radiosondes.

Observations collected by the APUAV during the Games were found to be comparable to measurements collected by other platforms such as microwave radiometers and in-situ sensors. New fast-response sensors are needed for the APUAV profiling to help generate better products for atmospheric profiling and monitoring applications. Its measurements are very useful for boundary layer (i.e., lowest levels of the atmosphere) applications, including modelling, forecasting and climate assessments.

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Figure 28. ECCC's UAV that was flown during the Games (left). A test flight of the UAV over the UOIT farmland in Oshawa, east of Toronto (right).

11.7 SUPERSITES

ECCC's researchers operate an enhanced meteorological observation site at Toronto Pearson International Airport, known as the "Pearson Supersite." Collecting data since 2007, the Supersite is home to a suite of specialized weather instruments that support research and development into short-term forecasting and nowcasting of high-impact weather at and in the vicinity of airports. Co-located with the existing staffed NAV CANADA weather observation station, the site is furnished with an icing detector, lightning sensor, multi-view camera system, specialized radar (vertically pointing X-band), horizontal visibility meter, multiple ceilometers to determine height of cloud base, and surface weather station with temperature, relative humidity and wind sampled at World Meteorological Organization standard measuring heights. The site also hosts a number of precipitation sensors including weighing gauge-type instruments and optical and radar-based systems. Multiple measurements of the same weather element allow for instrument intercomparisons, which facilitate the exploration and assessment of new observational technologies. From the Pearson Supersite, instrument data are transmitted to scientists in near real-time with a one-minute frequency for many of the instruments.

During the Games, these data were made available to support weather forecasting. Of particular interest were precipitation accumulations from the different sensors and profiles from the vertically pointing X-band radar. These radar data were used to distinguish between precipitation particle types such as ice crystals, snow, rain and drizzle at different heights in the atmosphere up to 8 km.

Beyond the Games, the Pearson Supersite will continue to be a key observational site and instrument testbed. Enhanced observations will support research and development efforts into aviation nowcasting, numerical weather prediction model verification and weather instrument performance evaluation.

A second supersite, the PUMS site (Pan Am and UOIT [University of Ontario Institute of Technology] Meteorological Supersite) was located at the UOIT Wind Farmland Campus in Oshawa, east of Toronto. This Supersite, which includes various new sensors, was designed for multi-purpose meteorological applications (see Figure 29). Its uniqueness comes from various state-of-the-art meteorological sensors. It has been developed over the last 10 years for measuring fog, visibility, precipitation, clouds, icing, radiative fluxes, wind and turbulence, and aerosol characteristics using state-of-the-art observing instruments and platforms. The PUMS measurements resemble measurements from a research aircraft. In addition to in-situ sensors, PUMS includes remote sensing platforms such as a Radiometrics Profiling Microwave Radiometer (PMWR) (a number of products relating to liquid water and water vapour in the atmosphere can be deduced from the radiation measurements), a Vaisala ceilometer (measuring the height of cloud bases), a microwave rain radar (MRR) (measuring rain rate, liquid water content and drop size distribution from near ground to several hundred metres) and an APUAV (taking meteorological measurements at different heights in the atmosphere; see Section 11.6). This site also had access to GOES-R operational weather satellite products that can be used for 3D analysis of weather processes.

The goals of this site were to: 1) compare PUMS observations with APUAV profiling flight measurements; 2) develop microphysical parameterizations for modelling applications; 3) validate satellite retrievals and modelling simulations during local meteorological events, e.g., lake-breeze effects and large-scale meteorological effects on local weather conditions; and 4) study precipitation variability over an area of about 2 km^2. In addition, this site provides specific observations to ECCC's scientists and those in UOIT who facilitate research and test the instruments' performance.

The main findings from the PUMS site will be used for model validations, new instrument development and testing, improvements in nowcasting, process studies of physical processes, and satellite validations for cloud and precipitation products.

Figure 29. Meteorological Supersite at the UOIT in Oshawa, east of Toronto, installed in support of the Games.

11.8 PAN AM COMMITTEE BOAT METEOROLOGICAL SENSORS

Two of the Pan Am Sailing committee boats were outfitted with meteorological sensors, which were similar to those in the land-based Mesonet (see Figure 30). These sensors provided invaluable, though infrequent, data by extending the surface data measurements over the lake. The boats (collaboration with two Toronto-area yacht clubs) were deployed about two hours prior to the start of all Pan Am sailing events, and then again during club races until the end of the sailing season in October 2015. There were no sailing events during the Parapan American Games.

The sensors were programmed to collect 1-second data of pressure, temperature, humidity, wind speed and direction. The data is processed to show 1-minute and 10-minute running averages and were available on the committee boats (10-second updates) and on the ECPASS Web display (10-minute updates) (see Section 11.10) to show very short-term and medium-term trends.

One of the remarkable observations was the fine-scale periodicity in both the wind direction and speed. The periodicity is of the order of about 6 oscillations in a 10 minute period. The wind direction and speed had variations (peak to peak difference) of about 15 degrees and about 1 m/s, respectively. This oscillation, which is critical to racing, would not have been seen with 1-minute data as with the land-based Mesonet data. This data display was quickly adopted by committee boat officials for race planning. The Doppler LiDAR was deployed to scan over the committee boats (particularly the "mobile" LiDAR) to produce Doppler wind maps for comparison and verification purposes.

© Reno Sit

Figure 30. Pan Am Games Sailing committee boat equipped with a Vaisala WXT520 compact weather sensor and an AIRMAR instrument with a magnetic flux compass for wind direction.

11.9 THE RESEARCH SUPPORT DESK – "NEXT GENERATION" FORECASTING, NOWCASTING AND ALERTING DEMONSTRATION

During the Games, ECCC research meteorologists conducted a "Next Generation Forecasting, Nowcasting and Alerting Demonstration" via two Research Support Desks (RSDs) in the OSPC area. The goal was to evaluate the "MetObject" approach and its ability to better integrate observations and numerical model guidance, and to facilitate forecaster interaction with semi-automated prediction and alerting systems. Since the MetObject approach involves multiple spatial and temporal scales—from continental scale to storm scale—the "optimal human machine mix" needed for effective analysis, diagnosis and prognosis of summer convective storms (e.g., thunderstorms) was investigated at each scale. High-resolution monitoring and numerical modelling, and other science showcase technologies, were also put to full use for this demonstration. The participating scientists provided important input to the forecasters in real time and will provide valuable information to ongoing projects post-Games.

11.9.1 FORECASTS TO 72 HOURS

MetObject forecast depictions were generated at "key frame" times (every 3 hours for day one, every 6 hours for days two and three) to show areas where thunderstorms and summer severe weather were expected in Ontario and surrounding regions, with a focus on the Games domain (see Figure 31). The MetObjects at key frames were interpolated to 10-minute intervals to allow generation of animations, and time series data at various points. The MetObjects at key frames were also used to derive new integrated MetObjects for use in "convective outlook" products.

Automated "first-guess" MetObjects were generated using a variety of guidance, including numerical weather prediction model-based thunderstorm parameters. A balance between "best data" and "best form" was investigated, since such a balance will be required in order for forecasters to make effective use of first-guess MetObjects.

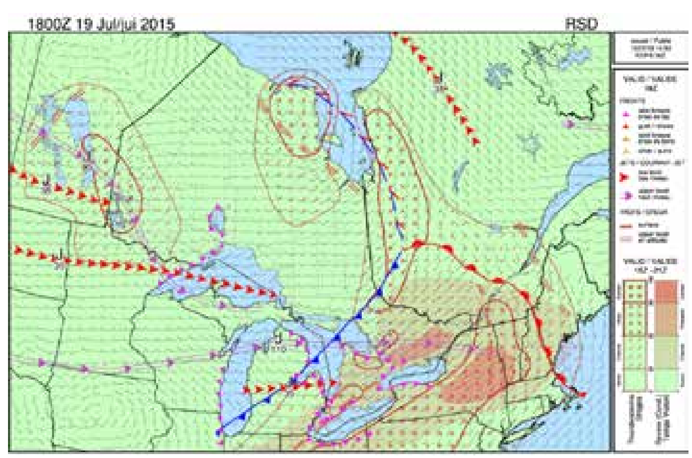

Figure 31. Example of an ECCC MetObject forecast depiction at a key frame time (18 UTC or 2:00 p.m. local time).

Collaboration between the two RSDs was evaluated, with each working at different temporal/spatial scales, then sharing resulting MetObjects to create collaborative products.

Subjective and objective near-real-time verification products were created so that forecasters could gauge their performance after the end of each shift and use that information to calibrate their efforts for the next shift.

11.9.2 HOURLY ANALYSES/1–2 HOUR NOWCASTS

Analyses of mesoscale features (for example, lake-breeze fronts) that positively influence the development or intensification of thunderstorms and related severe weather were performed hourly using the enhanced Mesonet monitoring data as well as operational radar and satellite data (see Figure 32).

Nowcasts of the development of new thunderstorms one to two hours into the future were made using data from the hourly analyses as well as rapid update cycle numerical model data.

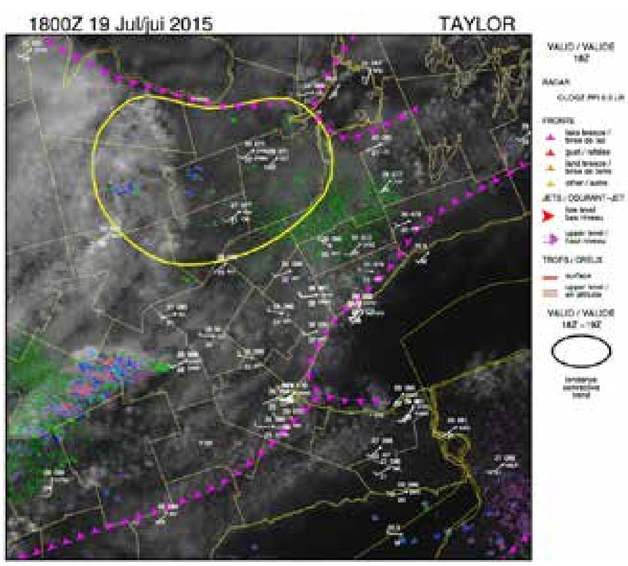

Figure 32. Hourly meteorological analysis in the Games region, valid for 18:00 UTC or 2:00 p.m. local on July 19, 2015. Magenta lines indicate positions of lake-breeze fronts. The yellow outline indicates an area where thunderstorms are expected to develop in the next one to two hours.

11.9.3 STORM-SCALE NOWCASTING TO 30 MINUTES

A new semi-automated approach for thunderstorm tracking, intensity trending and threat alerting was tested. It is anticipated that nowcasts of thunderstorm intensity will allow greater lead time for alerts.

11.10 ENVIRONMENT CANADA PAN AM SCIENCE SHOWCASE

An externally accessible, password-protected website was created to showcase science initiatives during the Games. The site, known as ECPASS (Environment Canada Pan Am Science Showcase) can be found at http://ecpass.ca. The website allowed real-time access to data from the following science initiatives:

- Next Generation Forecasting, Nowcasting and Alerting Demonstration;
- Automated nowcasts (lightning, INTW point forecasts, URP radar nowcasts);
- High-resolution urban scale meteorology model;
- Air quality model;
- Wave model;
- SOLMA 3D total lightning observations;
- Supersite observations at Pearson Airport and UOIT in Oshawa;
- Mesonet observations;
- AMMOS vehicle-based observations; and
- Doppler LiDAR.

ECPASS also served as the communications hub for science activities, with a blog (daily posts) and forum (real-time communication). More than 250 blogs and forum posts were written over the period covering both Games.

12 WEATHER AND HEALTH PORTFOLIO

Health and Air Quality Services is an umbrella activity of the MSC for the reporting and forecasting of weather-related health risks associated with air quality, heat, UV and others. Services developed under the umbrella are characterized by being driven by health stakeholders, prefaced on the objective of risk communications and often provided in support of those working to mitigate the impacts on the population most vulnerable to a specific health risk. A number of health and air quality projects were delivered in support of the Games, as described below.

12.1 PORTFOLIO APPROACH

The intent of the Portfolio's approach was to use the Games as a leveraged opportunity to launch the enhancement of existing MSC services and to showcase partnerships, technology and expertise that may lead towards future health and air quality services or support future considerations of MSC products and services.

The Portfolio exists within the Program (defined in this section as the health and air quality services program within the MSC), which maximized the inputs from science, monitoring, dissemination and modelling that supported the operations of the Games. Where possible, the Program sought to integrate activities to account for an all-hazards approach or to maximize efficiencies or opportunities (e.g., the numerical weather prediction urban-scale model output was made available to Public Health organizations [see Section 8.5.1]).

ECCC scientists wanted to obtain some indication of the value of those efforts from a stakeholder perspective. Towards those ends, we initiated a dialogue with our Public Health colleagues in the Games region in the spring of 2012 about our intent for the Games, and they provided input on our direction with specific elements of the Portfolio, specifically the user requirements for the Weather Health Information System for Decision Optimization and Management (WISDOM) portal.

Finally, the elements of the Program served as an umbrella for, in many instances, opportunistic activities adopted, co-opted or even adapted to support testing future health service directions of the MSC. The effort required to execute these activities ranged from the launch of a new service, multiple partner coordination and significant public profile to others. The common element for all of these was the objective of gaining a greater understanding of mechanisms and approaches to reduce societal health risks associated with weather.

12.1.1 THE POWER OF PARTNERSHIPS

The Games Portfolio was accomplished through relationships. Its final complement of activities was largely a process that often naturally happened as the Program approached colleagues and partners in the health and science community. The Program leveraged significant investment and in-kind support of many internal and external organizations in support of the Portfolio's agenda. Internal partners included representation from a number of divisions within ECCC. External partners included Health Canada, the Ontario Ministry of the Environment and Climate Change, Ministry of Health and Long-Term Care, Public Health Ontario, various Public Health Units, the University of Toronto and York University, the Ontario Association for Geographic and Environmental Education, the Ontario Sun Safety Working Group, and Esri Canada Education Group. Without the involvement and enthusiasm of these partners, this activity would have been a shadow of its final outcome.

12.1.2 EVALUATION

Finally, in conjunction with our goals and our commitment to stakeholders, we wanted to evaluate the success of executing the Portfolio. From an evaluation perspective, we kept the objective quite simple: *Did the execution of the Portfolio from the 2015 Games project improve the MSC Program relationship with external stakeholders?* While the program is still collecting specifics for the evaluation, there is anecdotal evidence that this has been accomplished.

12.1.3 WEATHER AND HEALTH PORTFOLIO THEMES AND ACTIVITIES

The Portfolio was comprehensive and extensive. Its scope was commensurate with that of the Program. Themes and activities within the Portfolio are shown in Table 2, with discussion on many of the activities provided in sections 12.2 and 12.3. Information on the science or modelling behind heat, air quality and UV is covered in other areas of this report (see sections 8.5.1, 8.5.3 and 11.5).

12.2 SERVICE ENHANCEMENT

The Games provided an opportunity for ECCC to operationalize new programs and enhance the service of others. Program staff began working with the stakeholders and internal processes/approval bodies early in the timeline to ensure that these services could be extended. These were all presented to the public and supported 24/7. None of these activities would have been possible without the support and the dedication of the ECCC forecasters and Warning Preparedness Meteorologists.

12.2.1 AIR QUALITY HEALTH INDEX

The AQHI is a communications tool that provides the health risk associated with the air that we breathe in our communities. The tool was developed collaboratively with Health Canada, the provinces, territories, local Public

Table 2. 2015 Games Weather and Health Portfolio themes and activities (bold activities are linked to ECCC's forecast operations and services)

THEME	ACTIVITY
Air Quality	• **Increase number of AQHI locations and provision of hourly forecasting for all locations and communities** • Enhance AQHI model resolution (GEM-MACH 2.5 km) • Firework: forest fire smoke modelling maps • Air Sensors for Chemicals in the Environment (AirSENCE) • Near Roadside Ultrafine Monitoring Study • Web-based mapping for traffic related air pollution and route planning • **AQHI implementation in Ontario (driven by the Games)**
Heat	• Multi-parameter weather monitoring network (Mesonet) • Urban-scale heat, humidity and stress indices predictions • Urban Heat Island/Population vulnerability mapping • **Implementation of new health-based-criteria for Heat Warnings**
UV	• Enhanced and geospatially presented UV forecasts • Investigation of cost-effective real-time UV monitors • Pilot warning with health stakeholders
Education	• OAGEE Pan Am Summer Institute on Weather and Health
Dissemination	• Weather Active – Heat and AQ smart phone application • ECCC weather information (https://weather.gc.ca), EC Alert Me, WISDOM
Decision Support	• Heat Alert and Response Table Top Exercise • Weather Health Information System for Decision Optimization and Management (WISDOM)

Health Units and media. The AQHI is given on a 1–10 scale, a similar concept to the use of scales for the UV index. In addition to observed AQHI values, forecasts for future conditions are provided with prescriptive health messaging to assist people in taking actions for reducing exposure to short-term air pollution.

The original AQHI program was announced in Toronto in the summer of 2007 as a pilot with the Province of Ontario and the City of Toronto. The Games provided the impetus to expand the coverage of the AQHI program prior to the Games and its eventual implementation for the summer of 2015, as well as to publicly test new forecast and reporting enhancements.

Working with the Ontario Ministry of Environment and Climate Change and with the Ministry of Health and Long-Term Care, ECCC and Health Canada were able to develop a phased approach for the Program starting in advance of the Games. This resulted in a partnership between the Ministry of the Environment and Climate Change and ECCC in issuing forecasts for the initial implementation, with meteorologists then assuming the role for AQHI forecasting early in 2015. The Ontario implementation was also unique in using a special derivative of the AQHI that accounts for health concerns associated with high concentrations of ground-level ozone (O_3). Ontario was the first jurisdiction in Canada to implement an AQHI warning service that could be triggered by this special consideration for high ozone concentrations.

During the Games, the Program tested the operationalization of a one-hour forecast product and the provision of site and community-based approaches to large urban centres (community or site-averaged AQHI values have been the norm for simplified communications in instances where there are multiple air quality monitors within a jurisdiction). Two additional AQHI reporting and forecasting locations were also installed for the Games, one at York University and the second at one of the new near roadside air quality monitoring sites at Hanlan's Point (on Toronto Centre Island). The OSPC provided one-hour AQHI forecasting for all of the existing and new locations starting in early July, prior to the Pan Am Games, and suspended the service in August following the termination of the Parapan Am Games. A description of the enhanced Program for the Air Quality Health Index was available to the public on ECCC's websites.

The response to the enhanced AQHI on the ECCC weather website indicated increased public interest in the enhanced program, including significant visitor use of the AQHI stations and the new hourly forecasts.

The lessons learned from this experience have resulted in an ambitious implementation of a nationwide rollout of the one-hour AQHI forecast program in early 2016, reversion of the air quality service back to Games levels in early 2016, and enhanced negotiations with other provincial partners on the timing and specifics around AQHI site reporting. The provision of the site forecasting was supported by the availability of the high-resolution air quality model, which is detailed in Section 8.5.3.

Figure 33. The enhanced Air Quality Health Index (AQHI) program included the addition of new air quality forecasts for the AQHI stations in Toronto and Hamilton (indicated by red squares on the map).

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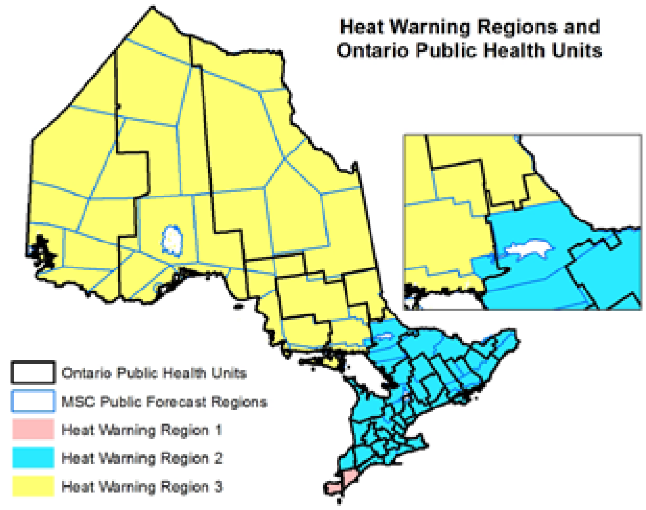
Figure 34. The new air quality monitoring station at Hanlan's Point on Toronto Centre Island. The station provided readings for the enhanced AQHI for the Games.



12.2.2 HEAT HEALTH WARNINGS

The Games provided an ideal opportunity to implement new impact-based triggers for heat warnings, which were developed through a multi-year collaboration of federal and provincial partners with Public Health Units. An analysis of health outcomes and corresponding temperature values led to the development of a multi-tiered (based on severity of the health risk), multi-regional warning map for the province of Ontario that served as the basis for a protocol drafted by the Ministry of Health and Long-Term Care for Public Health response unit response during the Games. The MSC also used the opportunity to implement a systematic early notification protocol, based on the above protocol, to provide early mobilization of the actors (Public Health Units, community health partners, etc.) involved in reducing the heat health risk, especially to those most vulnerable to those risks (e.g., the elderly and very young).

The new heat warnings and early notification service for all of Ontario was rolled out by ECCC in May 2015. The new heat warning regions in Ontario and heat warning criteria are provided in Figure 35.

HEAT WARNING REGION	CONDITION	DURATION
Region 1	*Tmax ≥ 31°C and Tmin ≥ 21°C OR Humidex ≥ 42	2+ days
Region 2	Tmax ≥ 31°C and Tmin ≥ 20°C OR Humidex ≥ 40	2+ days
Region 3	Tmax ≥ 29°C and Tmin ≥ 16°C OR Humidex ≥ 36	2+ days

Figure 35. ECCC's three Heat Warning Regions in Ontario and ECCC's Heat Warning criteria.
* Tmax represents maximum daily temperature. Tmin represents minimum nighttime temperature.

A post-Games meeting with the stakeholders (in late November 2015) confirmed the anecdotal feedback during the Games that the early notification service and the warnings significantly supported the health units in the Games area (and the multiple other early adopters) with the client-based prediction and broad dissemination necessary to support their heat health mitigation response. The lessons learned from summer 2015 will guide further fine-tuning of MSC service in support of the Ontario province-wide implementation of the Heat Alert and Response System (HARS) program, which will be implemented in the spring of 2016, as well as MSC's involvement with the Province of Alberta in implementing a similar service for the same time frame.

12.3 DEMONSTRATION PROJECTS

These were activities with ECCC and its partners, which were undertaken to demonstrate partnerships, science and monitoring technology. A sample of some of these activities is presented in sections 12.3.1 to 12.3.6 to show the breadth of the Portfolio.

12.3.1 WEATHER HEALTH INFORMATION SYSTEM FOR DECISION OPTIMIZATION AND MANAGEMENT (WISDOM)

WISDOM was developed to provide a portal for weather information deemed to be of interest to the health sector in decision making around the Games. To accomplish this in a cost-effective manner, the WISDOM GIS-based application was built within the Public Health Information Management System of Kingston Frontenac Lennox and Addington Public Health over a two-year period. The WISDOM portal was password protected and made available to select users starting in fall 2014. It was used by Toronto Public Health in winter 2015 to monitor their cold response plans.

WISDOM was used as a portal for MSC dynamic data of a geospatial operational nature. For example, some of the data available were:

- Real-time ECCC hourly Mesonet meteorological data (e.g., temperatures), including data from the existing network (e.g., airports);
- Current operational and high-resolution experimental Urban Scale NWP model output (showing standard meteorological variables as well as experimental products such as heat risk indices);
- AQHI real-time readings and forecasts for sites as well as experimental high-resolution Air Quality GEM-MACH 2.5 model output;
- Radar imagery;
- Firework smoke model for Canada, if needed, to determine the risk of forest fires in other parts of Canada on the Games;
- UV real-time observations and four-day UV model forecasts; and
- All MSC-issued alerts.

WISDOM also provided access to geospatial static data in layers. Each layer provided a visual representation of specific data to indicate types of vulnerability (e.g., indices to show social, material and economic deprivation, population demographics). These layers could be viewed individually or in groups to support decision making.

During the first week of July, 2015 WISDOM was used as a visualization tool for a "Summer Institute" for Grades 7–12 Ontario Geography and Science Teachers, an event co-sponsored by MSC along with the OAGEE (Ontario Association for Geography and Environmental Education), The Toronto District School Board, Ontario Institute for Studies in Education, and Esri Canada.

The WISDOM portal would not have been possible without much of this real-time and predictive data being available in a format that could be readily incorporated into the GIS-friendly formats. There have been many lessons learned from using WISDOM as a portal for visualizing both dynamic and static information. From these lessons, the MSC will better visualize forecast elements over the basic canvas of geospatial information.

12.3.2 NEAR ROADSIDE AIR QUALITY MONITORING

The Near Roadside Monitoring Project is a world-class, multi-agency monitoring study conceived to: evaluate and characterize the excess air pollution generated near major roadways; identify and understand the factors that contribute to the concentrations of traffic-related air pollutants; and to provide the data/experience to develop a national near roadside monitoring program. It involves the examination of air quality measurements from paired background and near roadside monitoring sites in Vancouver and Toronto. The study supported the reporting of the two background locations in Toronto (more representative of community levels of air pollution) as part of the enhanced AQHI reporting during the Games. There are four Toronto near road monitoring sites with study partners that include ECCC, the Ontario Ministry of the Environment and Climate Change (MOECC), and the University of Toronto. The intent is to expand the near road monitoring to Canadian cities with a population of at least 1 million by 2020. Figure 36 shows a near roadside monitoring station in Toronto, located beside major Highway 401.

Figure 36. Near roadside monitoring station near Highway 401 in Toronto (photo used with the permission of MOECC).

12.3.3 THE AIRSENCE AIR QUALITY MONITORING NETWORK

AirSENCE air quality monitoring devices estimate the concentrations of common urban air pollutants including ozone (O_3), nitrogen oxides (NO_x), carbon monoxide (CO) and particulate matter (PM). Real-time measurements are made and transmitted several times each minute to a central server, where they are converted to pollutant concentrations that can be viewed live through the Internet. The devices are being designed by a group of chemical engineers and chemists at the University of Toronto. The Health and Air Quality Services Program endorsed AirSENCE in the autumn of 2013, purchased sensor technology during its development and supported siting the sensors for the Games.

In summer 2015, a network of 10 prototype devices was deployed at sites across Toronto in conjunction with the Games. The sites were selected based on their proximity to Games-related events. The testing period started in mid-June and lasted until the end of August 2015. The primary goal of the study was to test the performance of the AirSENCE devices in the field (see Figure 37).

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Figure 37. An AirSENCE device on the University of Toronto downtown campus, showing the instrument's inner components (upper left, upper right). The AirSENCE devices measured air pollution in the Games area. The map (below) is from the AirSensors website (http://airsensors.ca) and shows the concentration of nitrogen oxides (NO_x), in parts per billion, at MOECC and AirSENCE sensors (photos and map used with the permission of MOECC).

A secondary goal related to communicating air quality information. For this, a publicly accessible website was developed to communicate real-time estimates of local air quality. Additional values from the provincial Ministry of the Environment and Climate Change air quality monitoring stations were also provided. Colour-coordinated estimates of the AQHI were posted along with estimates of individual pollutants. The interactive website also allowed users to see the contribution of individual pollutants to the AQHI, and to easily compare recent pollutant concentrations at different locations across the GTA. This website attracted considerable media interest, resulting in coverage by CTV News, Metro News, Metroland News and the University of Toronto website.

The study revealed design limitations in the devices, including their vulnerability to heavy rain and voltage spikes. Issues of calibration drift were also observed over time. Online data processing strategies were developed to partially address the drift issue. The lessons learned from this study are being incorporated into the design of the next generation version 3.0 of the device. These devices will be tested in Beijing, China, next year through a partnership with Airborne Underwater Geophysical (AUG) Signals and Peking University.

12.3.4 URBAN HEAT ISLAND DECISION SUPPORT FOR HEAT ALERTS AND RESPONSE SYSTEMS

Urban heat islands are a product of our built environment (see sections 8.5.1 and 8.5.3), and their impacts are expected to increase with climate change. Urban heat island effects are particularly important in the highly urbanized area of southern Ontario. A tool was subsequently developed to be used within the WISDOM platform to support decisions around heat warnings. This tool displays the typical hourly thermal patterns over the GTA during both daytime and nighttime. This is the first time that such high-resolution comprehensive temperature information has been available to Public Health Units.

The objective was to map the hourly spatio-temporal evolution of the Urban Heat Island (UHI) effect in the GTA during a typical summer heat spell, using air temperatures from the Mesonet and interpolation (i.e., data smoothing) methods that also used geographical layers of surface characteristics. Results indicate a strong lake-breeze effect from Lake Ontario, which is a result of large land-lake temperature differences during these cases. This is evident from Figure 38, which shows air temperature variability over the GTA during a July heat wave in the afternoon (1:00 p.m.) and night (11:00 p.m.). During the day, the lake breeze has penetrated inland (dashed arrow), giving cooler temperatures near the lake but higher temperatures further inland, reflecting the additional

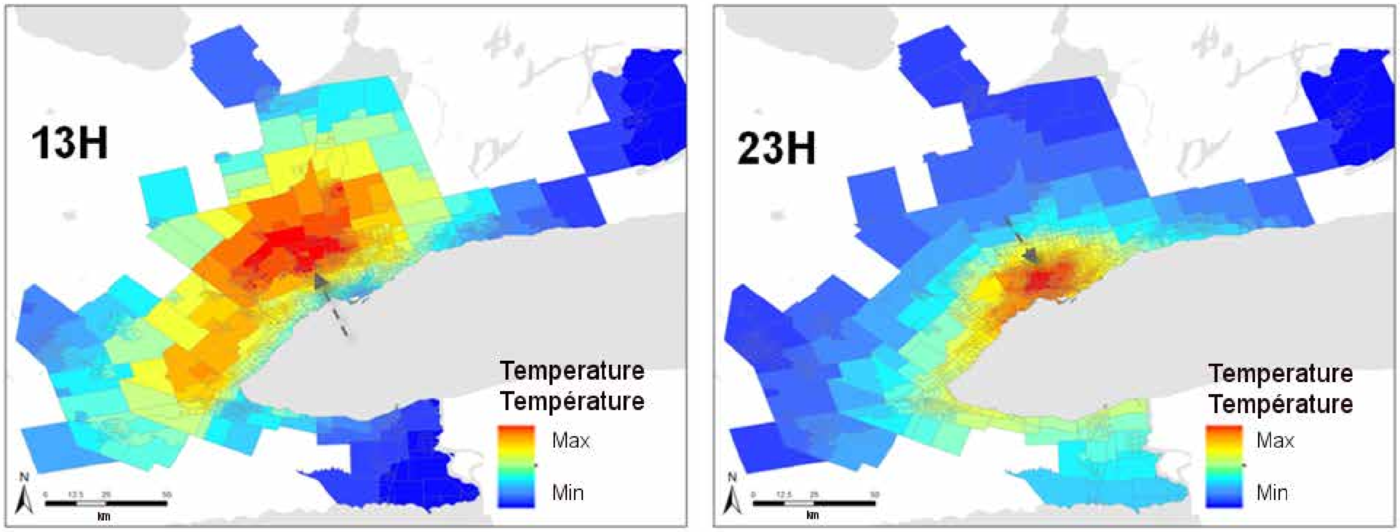

Figure 38. Interpolated observational air temperature fields at 1:00 p.m. local time (left) and 11:00 p.m. local time (right) during a heat wave in the GTA.

warming associated with the urban heat island effect. At night, the lake breeze shifts to a breeze from the land to the lake (i.e., land breeze). The warmer temperatures are advected towards the shore of Lake Ontario, while the additional warming associated with the urban environment maintains the higher temperatures shown over the City of Toronto. This type of detailed temperature information enabled health authorities during the Games to better target heat-vulnerable areas.

This tool provided a framework for health authorities to facilitate local interventions during extreme heat events in order to better target vulnerable areas. It also supported the further assessment of how representative airport temperatures are for issuance of heat warnings.

12.3.5 TESTING OF REAL-TIME UV SENSOR AND ENHANCED MODELLING

The MSC currently issues automated UV forecasts. The Games provided an ideal opportunity to investigate the means to significantly improve that UV service using a pseudo-AQHI approach of providing real-time information and enhanced forecasting to support decision making.

Four new UV sensors (as described in Section 5.6) were validated against the Brewer instrument, which is considered to be the “gold standard” for UV measurement. The new sensors were subsequently deployed in four locations in the GTA, providing the best spatial coverage to report hourly changes in UV and validating the new UV model (see Section 11.5). The real-time UV measurements and modelled UV future conditions were made available through the WISDOM platform, which allowed partners of the Ontario Sun Safety Working Group (OSSWG) to support their clients in taking protective measures against UV rays.

The OSSWG were very interested in the three new UV products that were available for the Games. Scientists are now analyzing the results from the demonstration product. When these results become available, Program principals will share them with the OSSWG to obtain their impressions of the service demonstration offered over the Games period. Plans are under way to leave the new UV instrumentation in place so that further validation of the model can be made.

12.3.6 WEATHER AND HEALTH SERVICE DISSEMINATION

The Games provided an opportunity to integrate weather and health themes into public dissemination pathways, which are being pioneered by internal and external partners. In addition to being a data contributor to the Ocean Networks website and guiding development of an early notification service for heat to the Public Health partners, the Weather and Health Program also situated select service enhancement and demonstration activities to test burgeoning MSC capability. The Program tested the issuance of a stakeholder product that would push an email to them when a predefined level of risk for UV or AQHI was reached. The Program also integrated new operational thresholds for heat warnings and Smog and Air Health Advisories/Special Air Quality Statements into public offerings.

In addition, Weather and Health Services was actively involved in the planning and execution of the Health Canada–funded, Toronto Public Health–executed "Weather Active" smart phone application. Throughout the summer, the application pulled relevant meteorological and air quality real-time forecasts and warnings for display in the smart phone application. The application was decommissioned in late October 2015, as it had been funded as a demonstration activity for the Games and to gather lessons learned on how to effectively disseminate and integrate the risk associated with heat and air quality. The Weather Active application won an award from the City of Toronto.

12.4 WEATHER AND HEALTH LEGACY

In conjunction with our goals and commitment to stakeholders, ECCC wanted to evaluate the success of executing the Portfolio. From an evaluation perspective, the objective was quite simple: Did the execution of the Portfolio from the Games project improve the MSC Program relationship with external stakeholders? While the Program is still collecting specifics for the evaluation, there is anecdotal evidence that this has been accomplished.

As with the evaluation, the legacy of the Portfolio is either being determined or is unfolding, making its presence known in the months and years to come.

By way of legacy for the Program, the new AQHI services will be rolled out nationally within ECCC based on capacity to execute and access metrics. EC Alert Me (see Section 9.6) was found to be a successful platform to test new AQHI service offerings such as the Smog and Air Health Advisory and the AQHI push messaging based on user-identified levels. More legacy items will be realized as time passes.

By way of intangibles, the Portfolio allowed the Program to showcase its activities internally as well as to science education, dissemination and other groups on its service areas of interest. Partnerships with the health (and education) community in the Games area have been strengthened; they are more aware of our business, our data, our capabilities and our commitment to support their decision making.

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13 COMMUNICATIONS

The Games were an excellent opportunity to highlight ECCC's contributions to a national and global audience. The Communications Branch worked with ECCC and federal partners to develop and deliver the Games communications program detailed below.

13.1 GOVERNANCE

The Department of Canadian Heritage (PCH) led the engagement of all federal organizations, including ECCC, through a Federal Communicators Network (FCN) within the formal federal coordination governance structure. The FCN coordinated all federal government communications efforts to support the Games. This was to ensure successful and consistent communications on behalf of the Government of Canada, and included the development and implementation of a communications framework, plan, processes, and procedures as described in the following sections. ECCC coordinated its communications planning and activities through the FCN, and in particular PCH as the federal lead.

The FCN served as the primary media contact during the Games. All media requests during the Games were to be directed to PCH, and where appropriate, specific requests for a particular department were forwarded to that department for response. Responses to weather-related media queries were shared with the FCN, as were the completed fact sheets.

ECCC Communications staff also worked with the ECCC Games Project Team and the FCN on the public safety and emergency elements of the communications plan. Key messages for possible scenarios were collected, written and shared with FCN members. Communications staff participated in ECCC table top exercises and planning meetings before the Games and advised on media protocols and processes. During the Games, Communications staff participated in the daily EFS teleconferences about issues of the day for situational awareness and to provide advice if necessary.

13.2 COMMUNICATIONS PLAN

A comprehensive communications plan was developed to leverage media and public momentum surrounding the Games by raising awareness about:

- ECCC's commitment to public safety with respect to its monitoring, products and services provided for high-impact weather events and environmental hazards;
- ECCC's leadership in scientific and technological innovation, particularly in the area of weather monitoring and forecasting to continuously improve its operational systems; and
- ECCC's partnership with other levels of government, universities, schools, Public Health Units and other stakeholders to enhance services for Canadians and visitors.

The communications plan included sustained communication through a variety of channels including media activities, a technical showcase, fact sheets, a media pitch, social media that included Facebook and Twitter, and internal communications.

Key messages for the Games focused on ECCC's role in assuring the safety and security of athletes, staff, volunteers and spectators. Specifically, the key messages were:

- ECCC is a primary partner in the delivery of the Games, providing enhanced weather monitoring, a venue-specific weather alerting program and environmental emergency response.
- ECCC's role in the Games will help ensure the safety of athletes, staff, volunteers and spectators.
- As part of its contribution to the Games, ECCC is developing cutting-edge technology for weather prediction and hazardous weather alerting, providing a legacy to benefit future generations of Canadians.

A proactive communications approach was recommended and implemented to help ECCC achieve its communications objectives.

13.3 INTERNAL COMMUNICATIONS

There were two facets considered for ECCC's communications surrounding the Project and preparation for the Games: internal and external. For our purposes, internal communications is defined as communicating the status of the preparation of the Project to senior management and staff within ECCC. Once the lead-up to the Games began with the Pan Am Torch Relay, communications shifted from a planning perspective to an operational perspective. Logically, following the Games, management wanted to be apprised of how the federal operations ran and what lessons were learned from the experience that could benefit the rest of the organization.

13.3.1 NEWS@ECCC

News@ECCC is a weekly internal email communications tool for employees at ECCC. A series of short articles was published by News@ECCC leading up to and during the Games to help employees understand and be proud of the Department's contributions to this event. The short stories highlighted everything from the torch relays to the closing ceremonies of each of the Games, and they included topics related to cutting-edge science being tested during the Games, the contingency role played by the Storm Prediction Centre in Winnipeg and the function of the briefing teams.

13.3.2 BUZZ@ECCC

Buzz@ECCC is a monthly tool for managers to engage employees in a conversation on key departmental priorities and initiatives. The June 2015 edition featured information about ECCC's contributions to the Games and highlighted some of the technology used during the Games.

13.3.3 INTERNAL PRESENTATIONS

Throughout the year leading up to the Games, during and following the Games, many presentations were conducted to inform senior management and colleagues about the Project Team's progress and our state of readiness. The impressions that were made were described as being significant because of the breadth of resources involved in the many facets of preparation leading up to the operations of the Games themselves. Presentations to senior management included ones to the Executive Management Committee, the Ontario and Quebec ECCC Councils, the ECCC Corporate Services Branch, and the MSC Forum and Management Committee. Between 2013 and 2015, yearly updates were given to ECCC employees during National Public Service Week.

13.4 EXTERNAL COMMUNICATIONS

It was important to prepare external messages for media, partners and stakeholders so that our enhanced services and products could be understood and properly presented for the Games. Here, external is defined as any person, group or organization outside of ECCC. The sections below outline what was accomplished for external communications before and during the operations of the Games.

Media interest provided a great opportunity to showcase the technologies used during the Games. The subject matter was very visual, so it lent itself well to television/video coverage. The broadcast reach for the outlets that covered the story included several million potential viewers in the Greater Golden Horseshoe Area, and indeed around the world for the Web content.

13.4.1 NEWS ARTICLES

In advance of the Games, interest from media led to stories in both regional and national media regarding the Mesonet as well as our roving AMMOS vehicles that provided data during the Games. These articles were prepared for *Maclean's*, the *Toronto Star* and the *Metro* (Toronto) newspaper. Any of the stories can be provided upon request.

13.4.2 TECHNOLOGY SHOWCASE/MEDIA DAY

To demonstrate and explain the cutting-edge science being studied by ECCC scientists, a decision was taken to host a technology showcase to communicate the details of what was involved. Media were invited to ECCC's Toronto office for a one-day event on June 23, 2015, where staff were available for filming, including interviews about the technologies that were being shown that day. Fact sheets, presentations and equipment were prepared relating to 10 subject areas. Project staff worked with communications advisors to plan the day and prepare the information to be presented. Crews from 2 of the 4 major Toronto television networks attended the event, and a third conducted interviews on another day (see Figure 39). There was also a live interview on a national morning show with one of the briefers. Additionally, there were a few print and Web articles covering the event. Most coverage from the technology showcase was published or broadcast during the two-week lead-up to the Games.

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Figure 39. ECCC's lead briefer at the TO2015 MOC (left) and marine network specialist (right) are interviewed by reporters on Technology Showcase day: June 23, 2015.

A separate media pitch was made to CBC, the official broadcaster for the Games, which yielded a more in-depth profile of ECCC's contribution to the Games. Ultimately, it resulted in three segments on our role in marine forecasting, the challenges of urban forecasting, and the expansion of the atmospheric monitoring network in southern Ontario for the Games.

13.4.3 FACT SHEETS

Fact sheets were prepared to describe a selection of the technologies and services that ECCC would be providing for the Games. These fact sheets were available at the Technology Showcase, and content from them was used in several reports and communications products.

Fact sheets were prepared on the following subjects:

- Compact Monitoring Stations;
- AXYS WatchKeeper™ Buoy;
- TRIAXYS™ Directional Wave Buoy;
- Upper Air Observations;
- Scanning Doppler LiDAR;
- Southern Ontario Lightning Mapping Array;
- Automated Mobile Meteorological Observing Stations (AMMOS);
- CRUISER (Canadian Regional and Urban Investigations System for Environmental Research);
- Weather and Air Quality Prediction Modelling; and
- Briefing Teams.

13.4.4 SOCIAL MEDIA, INCLUDING FACEBOOK AND TWITTER

In terms of social media for the Games, Tweets and Facebook posts were prepared for each Games period. For the Pan Am Games, there were 6 tweets posted to Twitter (3 in English and 3 in French). These tweets combined resulted in 34 retweets, 29 Favorites and 10 comments. The 6 Facebook posts (again 3 in English and 3 in French) resulted in 14 Shares, 194 Likes and 10 Comments.

A Spotlight story and photos (http://canada.pch.gc.ca/eng/1415036791050#a2)) were provided on the Canadian Heritage website.

13.4.5 EXTERNAL PRESENTATIONS

Presentations made externally by ECCC were equally important as those made internally to the Department. Early on, the presentations described what services could be offered to the TO2015 Organizing Committee and other partners. Once the services component of the Games had been accepted, the presentations evolved over the years to provide updated status reports on ECCC's preparedness and readiness for the Games. Following the Games, partners and other organizations were keenly interested in the story of ECCC's involvement, experiences and execution of the Project from planning through to project closure.

ECCC scientists delivered presentations to national and international audiences on the Science Showcase projects.

14 POST-GAMES

Post-Games, proper closure of the Project required that a number of activities take place and documents be written. All Mesonet monitoring platforms had to be removed from the field, decommissioned and tracked. The observational and forecast data was archived to be made available to national and international organizations. A number of final reports, evaluations and presentations were required. Senior management was briefed on the lessons learned over the life of the Project so that the larger meteorological program could benefit from those lessons.

The sections below describe the steps that were taken for each of the phases and stages preceding Project closure.

14.1 DECOMMISSIONING

The ECCC Mesonet was designed from the onset to be temporary. While the Parapan Am Games ended on August 15, the cost of deploying the Mesonet, its acknowledged utility, and the length of the existing land leases all supported a plan to leave the stations in the field until late fall 2015. Decommissioning of the network started in late October 2015 and was completed by mid-December 2015.

Forty compact stations and two spare stations were removed from their field locations and then taken to the ECCC Port Met Office in Burlington, Ontario, for decommissioning. The stations were disassembled into their component parts, which were distributed to national monitoring operations across the country from Nova Scotia to British Columbia. A large portion of the instrumentation was transferred to Science and Technology Branch, where it is being used to support projects in the Canadian Arctic. Two compact stations were left in operation for ongoing test and evaluation, one at ECCC's King City Radar site, and the second at MSC's headquarters office in Toronto.

The 10 ATMOS stations were removed from the field and stored as complete units for reuse by Science and Technology Branch as required.

The three standard MSC Auto8 monitoring stations that were installed at Uxbridge West, Mono Centre and Brantford Airport will not be decommissioned. National monitoring networks will assume ownership of these stations and continue operation for some years into the future. These stations will continue to provide valued reports to the MSC and the numerical modelling community.

The Canadian Coast Guard retrieved the WatchKeeper™ buoy and the TRIAXYS™ Directional Wave buoy for transport to the Port Met Office in Burlington. The buoys will be refurbished for use in the national marine network starting in the spring of 2016.

14.2 LEGACY DATASET AND ECOLLAB ARCHIVE

ECCC's enhanced atmospheric monitoring Mesonet weather observational dataset and associated metadata and information, as well as the forecasts and alerts produced for the Games, are part of a legacy for all Canadians. Recognizing this, ECCC has prepared a Legacy Dataset that will be available through the Government of Canada's Open Data initiative and associated web portal (http://open.canada.ca). Information in the dataset spans May 1 to August 31, 2015, covering both Games periods including the two torch relays. All data and information accessed from the portal will actually reside within ECCC's internal Data Catalogue. Eventually, the Legacy Dataset will expand to include scientific and research observations collected during that same period. The research datasets and their associated metadata will become available once validated and quality assured.

The Project documents, which are part of the ECCC legacy from the Games, tell the story of the planning, implementation and success of the Games Projects. ECollab, ECCC's intranet-based e-document management and collaboration solution, allowed for easy collaboration, management and sharing of Project documents among the Project Team. A special ECollab site dedicated to the Games Projects was developed in 2012, during the early planning stages. Over 200 Project Team members were registered users of the site. Key information files and images were stored on the site from ECCC's Project Office, Project Steering Committee, Monitoring, Prediction and Services, Science Working Groups, integration testing and table top exercises. As a result, the ECollab Games documents will be archived for the future.

14.3 EVALUATION

ECCC prepared a suite of questions for each of the three major clients with whom it interacted on a daily basis, as evidenced in the operations cycle described in Section 10. Canadian Heritage, the TO2015 Main Operations Centre and the RCMP federal security unit were asked, "What, during the Pan Am Games, were ECCC's strengths, weaknesses and areas needing improvement?" The questions were posed between the Games by an evaluation officer who was at arm's length from the Project, permitting interaction in an unbiased fashion. The interview was scheduled soon after the closing ceremony of the Pan Am Games so that, where possible, suggested improvements could be realized and attained prior to the commencement of the Parapan Games.

Soon after the Games ended in August 2015, the EFSWG developed a detailed evaluation of the interactions between representatives of federal departments and Canadian Heritage's Pan and Parapan Project Team. The questions were shared with the project teams across departments, weeks in advance of the evaluation interview to provide enough time to prepare responses. This proved to be invaluable, as many responses required detailed review of actions and reactions during the Games and departmental approvals.

14.4 BENEFITS ANALYSIS AND LESSONS LEARNED

As part of the PRINCE2® methodology for project management, two activities in particular are required of any project prior to its closure. The first activity is to perform a Benefits Analysis of the Project. It is a systematic process for calculating and comparing benefits and costs of a project. The Working Group leads at the Project start understood that new technologies, applications, techniques and products would be tested and evaluated. As the Project progressed, decisions were being made with a "cost for benefit" analysis in mind. Cost, time or capacity meant that some options were not viable. However, where last minute requirements arose, the Project Team strove to find a solution that benefited both the client and ECCC.

The final step in our Games projects was a Lessons Learned review designed to determine and analyze elements of the Project that were successful or unsuccessful. Throughout the Project, the ECCC Project Team tracked Lessons Learned, using the information in a timely manner where possible, or noted for long-term use where appropriate. Many of the insights gleaned from our experience are applicable to any "major events" that ECCC might be asked to support. For example, ECCC will assess all aspects of the Mesonet, including the minute-by-minute reporting and the high-spatial density layout. Much of the computer code and processing capabilities developed for the Games are available for use in the national weather monitoring networks.

15 CLOSING COMMENTS

During the lead-up years to the Games, many innovations and procedures, which were necessary for the teams to have equipment and staff in place, were implemented. There was a significant amount of testing required to assure optimal performance. Forecasters and briefers needed to be trained in the use of new hardware and software to ensure full utilization of Mesonet datasets, high-resolution numerical weather prediction and air quality model products that would be available to support the Games alerting program. This included contingency planning to determine and document alternate courses of action for the provision of services in the event of an outage of OSPC or either of the two briefing units. A series of five integration tests were conducted during an Intensive Operations Period to verify and validate that all instruments, workstations and staff were ready for the Games.


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The Games provided an opportunity for ECCC to test next-generation monitoring strategies, prediction models, forecast methods, data acquisition processes and distribution applications. Long-standing working relationships with national and international agencies were renewed and strengthened. There was close cooperation between the research and operations branches within ECCC, which led to the creation of a unified dataset that included all monitoring, forecasts and models used during the Games. This dataset is secured and available for use by the international community.

The Games team overcame many challenges, some foreseen, some emerging as they advanced closer to the launch of the Games. Overall, the weather services program was a successful effort that has left ECCC with new tools and an understanding of how to better support “fit-for-purpose” services at a fine scale for any large event.


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APPENDIX A – LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
3D	Three-dimensional
24/7 (/365)	24 hours per day, 7 days per week (/365 days per year)
AirSENCE	Air Sensors for Chemicals in the Environment
AMMOS	Automated Mobile Meteorological Observing Stations
APUAV	Atmospheric Profiling Unmanned Aerial Vehicle
AQHI	Air Quality Health Index
ATMOS	Automated Transportable Meteorological Observing System
AWOS	Automated Weather Observing System
CaPA	Canadian Precipitation Analysis
CARE	Centre for Atmospheric Research Experiments
CMC	Canadian Meteorological Centre
CO	carbon monoxide
CO_2	carbon dioxide
CRUISER	Canadian Regional Urban Investigation System for Environmental Research
DND	Department of National Defence
EC Alert Me	A service developed for the general Emergency Management Community to deliver weather and environmental alerts to subscribers
ECCC	Environment and Climate Change Canada (formerly Environment Canada)
ECPASS	Environment Canada Pan Am Science Showcase (Web portal)
EFS	Essential Federal Services
EFSWG	Essential Federal Services Working Group
FCN	Federal Communicators Network
FIFA	Fédération Internationale de Football Association
GEM	Global Environmental Multiscale Model
GEM-MACH	Global Environmental Multiscale – Model of Atmospheric Chemistry
GGHA	Greater Golden Horseshoe Area
GRCA	Grand River Conservation Authority
GTA	Greater Toronto Area
HARS	Heat Alert and Response System
HWOS	Human Weather Observing System
IFW	Integrated Forecaster Workstation
IM/IT	Information Management/Information Technology
IOP	Intensive Operating Period
IPAW	Integrated Pan Am Workstation
IRW	Integrated Research Workstation
ISW	Integrated Showcase Workstation
LiDAR	Light Detection and Ranging
Mesonet	A network of weather stations designed to observe mesoscale meteorological phenomena

ABBREVIATION	DEFINITION
MetObject	meteorological graphic object
MOC	(TO2015) Main Operations Centre
MOECC	Ontario Ministry of the Environment and Climate Change
MoU	Memorandum of Understanding
MPA	Multi-Party Agreement
MRR	Microwave Rain Radar
MSC	Meteorological Service of Canada
MTO	Ontario Ministry of Transportation
NAV CANADA	The corporation that operates Canada's civil air navigation system
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOAA	(United States) National Oceanographic and Atmospheric Administration
NoN	Network of Networks
NWP	numerical weather prediction
NWS	(United States) National Weather Service
O_3	Ozone
OAGEE	Ontario Association for Geographic and Environmental Education
OMNRF	Ontario Ministry of Natural Resources and Forestry
ONC	Ocean Networks Canada
OSPC	Ontario Storm Prediction Centre
OSSWG	Ontario Sun Safety Working Group
PASPC	Prairie and Arctic Storm Prediction Centre
PCH	Department of Canadian Heritage
PEOC	Provincial Emergency Operations Centre
$PM_{2.5}$	fine particulate matter
PMWR	Radiometrics Profiling Microwave Radiometer
PRINCE2®	PRojects IN Controlled Environments, version 2
RCMP	Royal Canadian Mounted Police
RSDs	Research Support Desks
S&T	Science and Technology Branch
SAHA	Smog and Air Health Advisories
SLA	Service Level Agreement
SOLMA	Southern Ontario Lightning Mapping Array
TO2015 Games	Toronto 2015 Pan and Parapan American Games
TRCA	Toronto and Region Conservation Authority
UAV	Unmanned Aerial Vehicle
UCC	Unified Command Centre
UHI	Urban Heat Island
UOIT	University of Ontario Institute of Technology
UQAM	Université du Québec à Montréal

ABBREVIATION	DEFINITION
UTC	Coordinated Universal Time
UTCI	Universal Thermal Climate Index
UV	Ultraviolet
WBGT	Wet Bulb Globe Temperature
WISDOM	Weather Health Information System for Decision Optimization and Management
XML	Extensible Markup Language

Additional information can be obtained at:

Environment and Climate Change Canada
Public Inquiries Centre
7th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800
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