Environmental Emergency Response at the Canadian Meteorological Centre

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Abstract

The Environmental Emergency Response (EER) section at the Canadian Meteorological Centre (CMC) provides guidance for emergencies and incidents involving atmospheric transport and dispersion of pollutants on geographic scales ranging from metres to global and on time scales ranging from minutes to over a week. Its mandate is defined by National and International arrangements, and includes airborne volcanic ash, forest fire smoke, radiological isotopes, and pollutants released in industrial accidents such as chemical fires. In the case of incidents within Canada, the EER section provides support at the request of Environment Canada's Regional Environmental Emergency Teams (REET). It runs a suite of atmospheric transport and dispersion models that contain physical algorithms for transport, turbulent dispersion, deposition, and isotope decay. The transport models require accurate inputs of evolving 3D weather conditions, which are produced by CMC's operational global analysis and prognosis system. Other key elements needed to ensure a quick and efficient response include 1) defining as accurately as possible the parameters that characterize the incident: for example, pollutant involved, amount and release rate, size of the fire, height of the release, etc. 2) Clear and well defined procedures for requesting services and disseminating results. An example of an actual real-time response for an event in Canada is presented.

1 Introduction

Following the Chernobyl reactor disaster in 1986, a decision was made that the Canadian Meteorological Centre (CMC) would establish an expert group in operational modelling of long-range atmospheric transport and diffusion of radioactive pollutants. This group would supply modelling support in real or near-real time in the event of releases of radioactive material. At the same time, this Environmental Emergency Response (EER) section would also provide modelling support for more localized releases. Now, more than 20 years later, CMC has an EER section with a 24/7 operational response mandate for both national and international environmental emergencies, consisting of 2 meteorologists, 4 scientists, and 3 computer scientists.

In this article, a brief description is given of the international responsibilities of CMC's EER, followed by an outline of how CMC and EER fit into the emergency response structure of Environment Canada. The atmospheric transport models used at CMC are presented, and the computational infrastructure is described. A discussion follows on the importance of correct communication procedures, both in requesting modelling support, and in disseminating and interpreting the modelling results. The article concludes with an example of a response by CMC's EER that demonstrates the impact of correct meteorological inputs.

2 International Mandates

In 1993, the CMC was designated by the World Meteorological Organization (WMO) and the International Atomic Energy Agency (IAEA) as a Regional Specialized Meteorological Centre (RSMC), responsible for providing atmospheric transport modeling advice during nuclear emergencies. Presently there are eight RSMCs providing global coverage.

The support provided consists of running the global transport model to predict the spread, concentration, and deposition of released radionuclides, and disseminating the results to appropriate recipients.

Environment Canada, in agreement with the International Civil Aviation Organization (ICAO), designated CMC as a regional Volcanic Ash Advisory Centre (VAAC) in 1994. The same long-range model used for prediction of radionuclide transport and dispersion can be used to model the evolution in the atmosphere of volcanic ash plumes, a highly significant hazard for aviation. VAAC Montreal is one of nine centres world-wide.

CMC also provides support to the Provisional Technical Secretariat of the Comprehensive Test Ban Treaty Organisation (CTBTO), as part of the global receptor-oriented verification system. CMC uses inverse transport modeling to help link the detection of radionuclides to possible sources.

3 National Mandates and Program Drivers

CMC supports lead response organizations within Canada for a number of situations:

- Nuclear emergencies, as a partner in the Federal Nuclear Emergency Plan (FNEP), and with Health Canada;
- Atmospheric toxic spills & local emergencies, upon request by Regional Environmental Emergency Teams (REET);
- Natural hazards, such as forest fires, volcanic eruptions.
- In conjunction with Foreign Affairs and the International Trade Ministry, CMC is part of the Canadian Authority for CTBT.

The EER section is an active partner in National Defence CRBNE Research and Technology Initiative (CRTI) projects. The active partner is the Radiation Protection Bureau of Health Canada.

4 CMC Models Supporting Emergency Response

As part of its operational global analysis and prognosis system, CMC maintains a set of state-of-the-science Numerical Weather Prediction (NWP) models that analyse and predict weather around the globe, around the clock. The outputs of these models – wind, temperature, humidity, stability, etc. - serve as inputs to the transport-dispersion models which then predict the movement of pollutants in the atmosphere. The impact of accurate inputs to the transport-dispersion models is especially significant when in cases where the weather is changing – in particular wind speed and direction.

4.1 Numerical Weather Prediction

The backbone of NWP at CMC is the Global Environmental Multiscale (GEM) model, which is a complete primitive-equations model with full physics that provides weather forecasts over Canada for up to 10 days. GEM is configured to run operationally at a horizontal resolution of 33 km globally, 15 km regionally over North America, and at 2.5 km over sensitive coastal and populated areas. All three configurations use 58 vertical levels that extend from the ground upwards to 30 km. The global and regional GEM configurations update the analyses and forecasts every 6 hours, while the 2.5 km model is re-run every 12 hours.

4.2 Transport-Diffusion Models

The EER section employs a suite of models, all developed at Environment Canada. Their usage depends on the situation and the desired product.

The simple Trajectory model can be used to model the future (or past) trajectory of a small number of air parcels released (or arriving) at a point, using winds supplied by GEM. Running the model backwards in time is useful for obtaining a rapid estimate of potential locations of a pollutant source.

The Canadian Emergency Response Model (CANERM) was first applied to the Chernobyl case to demonstrate the utility of Eulerian transport modeling (Pudykiewicz). In addition to transport and turbulent diffusion, it takes into account the removal of pollutants from the air due to gravitational settling, wet scavenging, surface deposition, and radioactive decay. CANERM can be run in either forward or backward mode. Horizontal grid size and resolution can be varied, up to hemispheric in extent for long range transport (5 or more days).

Lagrangian models, of which there are three, are used for situations involving smaller scales (Thomson, 1987). The zero-order “Modèle Lagrangien de Dispersion de Particules” (MLDP0), adds a random displacement of air particles in a background wind field supplied by GEM. The random displacement simulates the chaotic movement of particles in a turbulent wind field.

There are two first-order Lagrangian models; “first-order” indicates that the turbulent wind fluctuations are simulated by adding a random fluctuation to the provided wind field before computing the resulting particle motion (Wilson and Sawford, 1996). This technique has more physically realistic properties than the zero-order one.

“Modèle Lagrangien à Court Distance” (MLCD) is the simplest of the Lagrangian models, and the quickest to run. It is intended for small-scale and short time periods, typically less than 100 km and 12 hours. It requires inputs of wind at one or more levels, precipitation, surface roughness, and atmospheric stability. The model is able to take into account changes in these quantities with time. Either GEM output or user-entered values can be used. Since the MLCD grid is relatively small, meteorological conditions for this model are uniform across the domain.

The first-order “Modèle Lagrangien de Dispersion de Particules” (MLDP1) is designed for either short or long range. As with MLDP0, The meteorological fields vary over the 3D grid, making it more realistic than MLCD, but more computationally expensive than the others.

The above models all include a source model that allows the user to specify the amount of material, the shape and size of the initial release (e.g. puddle, fireball, column), its duration, settling rate, and, in the case of nuclear material, the isotope(s). Although removal from the atmosphere due to radioactive decay is computed, there is presently no account taken for any resulting radionuclide offspring.

As part of recent CRTI projects, a prototypical Urban Lagrangian Stochastic model (UrbanLS) has been developed and tested at CMC, and is anticipated to become an integral member of the EER modeling suite (Wilson et al., 2009). UrbanLS requires the most preparation: it requires either GEM or observed meteorology that has been run through a CFD processor (UrbanSTREAM) that combines the meteorology with information about building structures (urban shape files) to create realistic turbulent flows for urban areas with tall buildings. The scales are on the order of metres, and the time scale is up to 30 minutes, depending on how rapidly the weather is evolving. Currently, shape files for downtown Montreal, Ottawa, and Vancouver have been used to test various scenarios for those cities. At this time, only a simple dry-deposition scheme is available.

As with CANERM, both MLCD and MLDP0 can be run in backwards mode. The inverse MLDP0 is what is used for the CTBT backtracking program.

4.3 Computational Tools

The computational resources at CMC range from the supercomputer on which GEM analysis and forecast cycles are run, to the Linux desktop workstations. The transport-dispersion models can be run on the local "front-end" workstations, but better performance for CANERM, MLDP0, and MLDP1 is achieved by running on the "back-end" supercomputer.

An essential tool used at EER is the graphical tool-kit SPI, developed in house. This is a fully 3D data-rendering software that is fully integrated with the emergency response models, and serves as the principal developmental and operational user interface. Models can be run from the tool-kit, and results visualized, analyzed, and formatted for presentation.

5 Response Procedures for an Emergency in Canada

The EER procedure at CMC begins when a request is received from a Regional Environmental Emergency Coordinator (REEC). The number of occurrences that come to the attention of the REECs is considerable; however, most do not lead to a requirement for atmospheric transport modeling. In order to avoid unnecessary modeling efforts, the REEC is an essential "clearing house". However, requests from other organizations are considered on a priority basis.

Once model results are ready, they are transmitted to the clients designated in the request.

Problems can arise if a request for support arrives at CMC that contains inaccurate and/or insufficient information. At a minimum, the precise location and the type of incident ("fire", "explosion", "slow leak") is required. Additional useful information includes: the pollutant involved, the amount and/or release rate, the dimensions of the fire, the height of the release. Experience has shown that very often, little other than the location and the type of the release is known initially. Additional information may arrive later that enables better modeling, e.g. substance, amount, duration of release. It is then possible to rerun the model(s) as more information arrives. However, this could lead to the circulation among clients of multiple versions of EER model output, and confusion may result. Adhering to the communication procedures via the REEC and its designated officers and contacts will do much to reduce the chances of this occurring. Ideally, additional information should refine – but not substantially alter – what was provided earlier.

Commercial atmospheric dispersion software exists that can be quickly run on laptops by lay-people. While the convenience of commercial models cannot be disputed, great care must be exercised. The results from a model are highly influenced by the parameters employed. Knowledge of the physical and chemical properties of the material, and of changing weather conditions, is vital. Such a case will be presented in the following section.

6 An Example of Emergency Response: the Edmundston Tire Fire

Early on the morning of June 1, 2008, a fire broke out at a tire-disposal facility near Edmundston, New Brunswick, leading to concerns about the effect of SO_2 on the nearly population. EER was initially given the time and street address of the fire. Further information provided estimates of the release rate of SO_2 that enabled further refinement of the source term for a second model run.

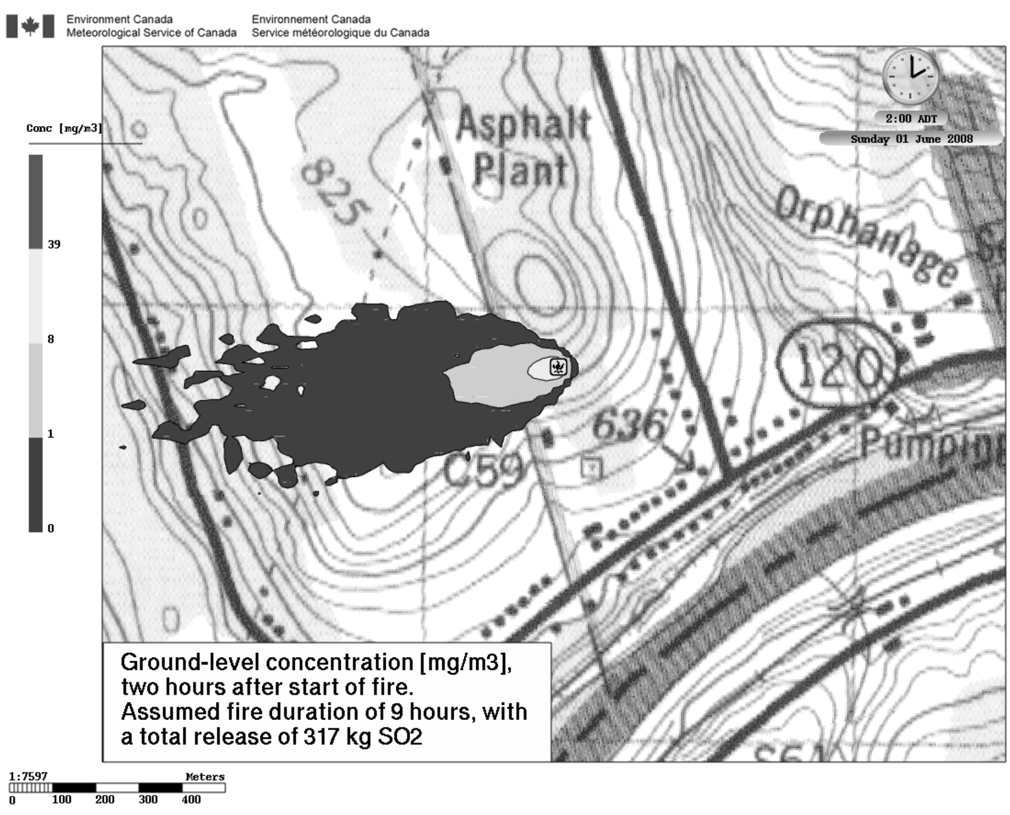

Figure 1 - Ground-level concentration, 2:00 local time on June 1, 2008. Colour bars represent ERPG threat levels of 39, 7.9, and 0.79 mg/m^3 (ERPG3, ERPG2, and ERPG1). The darkest colour in the plume indicates values below 0.79 mg/m^3.

One interesting aspect of this case is that the wind direction almost completely reversed over the course of a few hours. Initially the smoke drifted westward

(Figure 1), but as the wind shifted (Figure 2), the plume moved toward more densely-populated areas (and in the direction of the U.S. border).

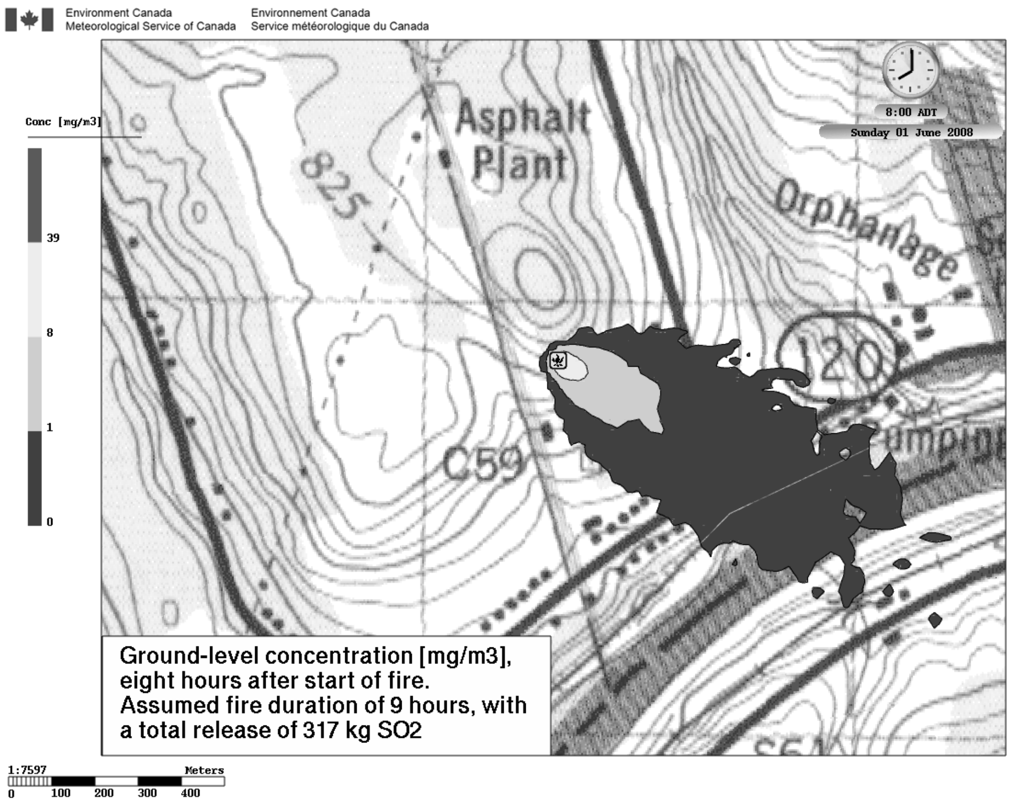

Figure 2 – As Figure 1, at 8:00 local time.

7 Conclusion

The mandates and activities of the Environmental Emergency Response section of the Canadian Meteorological Centre have been presented. The models used have been briefly described. An example of an emergency response has been given that highlights the need for accurate meteorological input.

8 References

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