



RSMC MONTRÉAL USERS' INTERPRETATION GUIDELINES ATMOSPHERIC TRANSPORT MODEL OUTPUTS

Version 11

Environmental Emergency Response Section
RSMC Montréal
Canadian Meteorological Centre
Meteorological Service of Canada

Environment Canada

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1. Introduction

The Canadian Meteorological Centre (Meteorological Service of Canada, Environment Canada) is designated as the Montréal Regional Specialized Meteorological Centre (RSMC) by the WMO for the provision of atmospheric transport model in case of an environmental Emergency Response. The primary regions of responsibility (regional associations) are WMO RA-III & IV: Canada, United-States, Mexico, Central and South America. This document provides a description of RSMC Montréal products.

2. The Canadian Meteorological Centre

The Canadian Meteorological Centre (CMC) is an important component of Environment Canada's Meteorological Service of Canada (MSC). CMC is Canada's national meteorological centre and it operates 24/7 around the clock. It provides a variety of essential numerical weather prediction (NWP) products and services to national and international users. It houses one of the largest supercomputing centres in the country and supports national telecommunications networks and facilities as well as the national climate archives.

At CMC, the Research and Development personnel work closely with the Centre's Operations Branch to ensure that the operational requirements are met and that the operational NWP systems are at the leading-edge of science and technology. CMC runs its operational suite of computer analysis and forecast models on an IBM supercomputer and LINUX clusters, both with backup. Telecommunications functions are provided by computers with a WMO GTS link to the Washington Telecommunication Hub and a backup link to Exeter, UK.



Experienced meteorologists, computer specialists, and technical staff perform operational duties around the clock to monitor and control the NWP forecast production and dissemination systems. Other specialists are on call on a 24/7 basis to lend additional support such as in the event of an environmental emergency.

The atmospheric transport and dispersion modeling capacity benefits from all of the Centre's fully operational facilities and tools which are part of the well established NWP forecast production system. Current global weather conditions and forecasts are constantly available to provide in real time the necessary input to the atmospheric transport and dispersion models and for their evaluation and interpretation. Archived past data can be retrieved for historical simulations.

For NWP, the Global Environmental Multiscale (GEM) model is used by CMC operations. Two configurations are available: regional and global. The latter, which has a uniform resolution over the globe, is used to provide quality analyses, through the assimilation cycle, and medium term forecast guidance. A comprehensive set of graphical and alphanumeric products is available from the two configurations of the GEM model.

3. Atmospheric transport and dispersion modelling

The trajectory model is a simple tool designed to calculate the trajectory of a few air parcels moving in the 3-D wind field of the atmosphere. The model is described in D'Amours & Pagé, 2001. Only transport by the winds is considered without taking into account any other physical or atmospheric processes. The advection of an air parcel is computed according to a Runge-Kutta scheme.

The model estimates the trajectories of the parcels, originating from or arriving at the same geographic location, but for different levels in the vertical. The location and levels are defined by the user. The model can be run to obtain a quick estimate of the expected trajectory of an air parcel, whose point of origin or point of arrival (back trajectory) is specified as the input parameter.

MLDP0 (*Modèle Lagrangien de Dispersion de Particules d'ordre 0*) is a fully 3-D Lagrangian model for medium and long range transport of pollutants in the atmosphere. MDLP0 replaced the CANadian Emergency Response Model (CANERM) in March 2009 as the operational model of RSMC Montreal. It is a Lagrangian Particle dispersion model of zeroth order described in details in D'Amours & Malo, 2004. In this model, dispersion is estimated by calculating the trajectories of a very large number of air particles (or parcels). The trajectory calculations are done in two parts: 3-D displacements due to the transport by the synoptic component of the wind, then 3-D displacements due to unresolved turbulent motions. Vertical mixing caused by turbulence is handled through a random displacement equation based on a diffusion coefficient. This coefficient is calculated in terms of a mixing length, stability function, and vertical wind shear. Lateral mixing (horizontal diffusion) is modeled according to a first order Langevin Stochastic Equation for the unresolved components of the horizontal wind (mesoscale fluctuations).



MLDP0 is an off-line model and uses the full 3-D meteorological fields provided by an NWP system. Therefore, fields of wind, moisture, temperature and geopotential heights must be provided to the model, which are obtained either from the GEM operational data assimilation and forecast system in the Global or Regional configuration.

Dry deposition is modeled in term of a deposition velocity. The deposition rate is calculated by assuming that a particle contributes to the total surface deposition flux in proportion to the tracer material it carries when it is found in a layer adjacent to the ground surface. Wet deposition will occur when a particle is presumed to be in a cloud. The tracer removal rate is proportional to the local cloud fraction.

The source term is controlled through a sophisticated emission scenario module which takes into account the different release rates of several radionuclides over time. For volcanic eruptions, a particle size distribution can be used to model the gravitational settling effects in the trajectory calculations according to Stoke's law. The total released mass can be estimated from an empirical formula derived by Sparks *et al.*, 1997, which is a function of particle density, plume height and effective emission duration.

In MLDP0, tracer concentrations at a given time and location are obtained by assuming that particles carry a certain amount of tracer material. The concentrations are then obtained by calculating the average residence time of the particles, during a given time period, within a given sampling volume, and weighting it according to the material amount carried by the particle. Concentrations are expected to be estimated more accurately near the source with this Lagrangian model than with an Eulerian model.

The model operates on a polar stereographic grid and can run on both hemispheres. The grid size and resolution define the geographical domain. Six horizontal grid resolutions are available:

- 50 km (687×687, 477×477, 400×400 and 334×334)
- 33 km (722×722, 606×606, 505×505, 400×400 and 229×229)
- 15 km (503×503 and 251×251)
- 10 km (229×229)
- 5 km (457×457)
- 2 km (300×300)

A global configuration also exists at horizontal resolution of 1° (360×181). MLDP0 can be executed in inverse (adjoint) mode. The model has been used extensively in this configuration in the context of the WMO-CTBTO cooperation. The vertical discretization is made for 25 levels in the SIGMA, ETA or HYBRID terrain following coordinates depending on the version of the NWP model used.

The model can be used for several types of applications:

- Medium range problems (from 10 to 100 km)
- Long range problems (>100 km, up to ~10⁴ km)
- Simulations up to 10 days in forecast mode (up to 30 days in hindcast mode)



- Complex meteorological conditions & topography
- Volcanic eruptions
- Nuclear accident (multiple radionuclides)
- Foot-and-Mouth Disease (FMD) virus
- Toxic material fire, chemical release, forest fire, sand dust storm

MLDP0 is fully integrated into the operational setup of the CMC. At any time, its execution can be requested by the duty meteorologist. MLDP0 uses meteorological fields provided by the global data assimilation system in historical mode, or by the GEM model, in forecast mode. In historical mode, the last 2-3 days are kept on-line for fast access. Beyond that, archived data can be retrieved from tape in a matter of minutes. In forecast mode, data are available to 144 hours for the 12 UTC run and to 240 hours for the 00 UTC run.

References

D'Amours, R., Malo, A., 2004, *A Zeroth Order Lagrangian Particle Dispersion Model MLDP0*, Internal Publication, Canadian Meteorological Centre, 19 pp, available at <http://eer.cmc.ec.gc.ca/publications/DAmours.Malo.2004.CMC-EER.MLDP0.pdf>

D'Amours, R., Pagé, P., 2001, *Atmospheric Transport Models for Environmental Emergencies*, Internal Publication, Canadian Meteorological Centre, 9 pp, available at http://eer.cmc.ec.gc.ca/publications/DAmours.Page.2001.CMC-EER.Trajectoire_CANERM_e.pdf

Sparks, R. S. J., Bursik, M. I., Carey, S. N., Gilbert, J. S., Glaze, L. S., Sigurdsson, H., and Woods, A. W., 1997, "Volcanic Plumes", *John Wiley and Sons*, New York, 574 pp.




4. Description of the MLDP0 output maps for a hypothetical default scenario

Figure 1 presents a labelled output map as obtained from an MLDP0 forecast using the default scenario. The labelled items are as follows:

(1): **Source name:** Identification of the source site or incident.

(2): **Source location:** Latitude and longitude of the source in decimal degrees.

(3): **Source symbol:** The location of the source is identified on the map by the radioactivity symbol .

(4): **Date of release:** Identifies the date (month, day and year) and time (hour and minute) of the release (UTC).

(5): Identification of the field that is plotted on the map. With the default scenario, the following maps are produced:

i) **Time integrated surface to 500 m layer concentrations:** Time integrated surface to 500 m layer concentration for the 24-hour period ending at 24 UTC (for a release occurring between 00 and 12 UTC) or ending at 12 UTC (for a release occurring between 12 and 24 UTC) for the time period given in item 6. The time integration is done within the first 500 metres above the model ground.

NOTE: For the first 24-hour period, the actual integration is done starting at the release time and ending at either 12 UTC or 24 UTC. As a result, the time elapsed from the release to the end of the period will generally be less than 24 hours. However, the value integrated over this shorter period is the same as the value obtained when integrating over the full 24 hours. For example, if the release occurs at 06 UTC, the 24-hour period for the integration will end at 24 UTC. Since the source is assumed to be zero between 00 and 06 UTC, there is no contribution to the integrated value for that portion of the 24-hour period. Thus the integrated value from 00 to 24 UTC will equal the contribution from 06 to 24 UTC.

ii) **Total deposition:** This is the total (wet and dry) deposition for the time period given in item (6) (the above NOTE applies here also). For the default scenario, the time period is 72 hours.

(6): Dates and times over which the fields in item (5) are calculated.

(7): **Release scenario and dispersion model details:** Indicates that the following information describes the release scenario and some important parameters used by the dispersion model (items 8 through 19).



(8): Isotope: Indicates the type of radionuclide used in the modelling. Caesium 137 (^{137}Cs , half-life of ~30 years) is the default radionuclide.

(9): Total release duration: Indicates the total length of time of the release. The default release duration is 6 hours.

(10): Horizontal wind velocity variance: This parameter is used to model the mesoscale fluctuations within boundary layer height as well as in free atmosphere. The default value is defined at $1 \text{ m}^2/\text{s}^2$.

(11): NWP meteorological input model: Indicates the NWP forecast data used as input to the dispersion model. The default meteorological model is the GEM in the Global configuration.

(12): Output grid resolution: The horizontal grid length, in km, used by the dispersion model for the concentration and deposition calculations. The default output horizontal grid resolution is 33 km.

(13): Atmospheric dispersion model: Indicates the name of the atmospheric transport and dispersion model: MLDP0.


(14): Total release quantity: Total mass of pollutant released from the source associated to the radionuclide involved in the simulation. This amount is expressed in term of radioactivity and the default value is 1 Bq.

(15): Initial maximum plume height: Indicates the maximum height reached by the plume at the beginning of the release. The default value is 500 m AGL.

(16): Initial column radius: Indicates the initial distribution radius of the particles in the horizontal within the emission column. The default value is defined at 100 m.

(17): Vertical distribution: Indicates the type of function that is used in the model to distribute in the vertical the particles within the release plume. By default, the particles are distributed uniformly in the vertical between the surface and 500 m AGL.

(18): Number of particles: Indicates the number of Lagrangian particles released from the source associated to the selected radionuclide. The default value for the number of particles is defined at 50000.

(19): Maximum value at o: An 'o' indicates the location on the map of the maximum value. Units are $[\text{Bq}\cdot\text{s}/\text{m}^3]$ for the 24-hour time integrated concentrations and $[\text{Bq}/\text{m}^2]$ for total deposition. If the maximum concentration is in the vicinity of the source, it may be hidden by the symbol  that indicates the location of the source.

(20): Contour values may change from chart to chart: This warning message is indicated on each map to warn the user that contour values may vary from chart to chart.



(21): Units corresponding to items (5) and (22): [$\text{Bq}\cdot\text{s}/\text{m}^3$] for the 24-hour time integrated concentrations and [Bq/m^2] for total deposition.

(22): Identification of the four concentration/deposition contours in powers of ten. Note that the contours may vary from one map to another as indicated by item (20).


(23): Indications related to the event itself for the simulation. Possible values are **REQUESTED SERVICES, IAEA NOTIFIED EMERGENCY** and **TEST/EXERCISE** (default notification).

(24): RESULTS BASED ON DEFAULT INITIAL VALUES: This indicates that the default release scenario is used.

5. Complete set of MLDP0 output maps for a hypothetical default scenario

Figures 2 through 10 present a complete set of output maps for the default scenario. For these maps, the following items are identical:

(1): The source is Gentilly (Québec, Canada) nuclear power station.

(2), (3): The location is at latitude 46.40 decimal degrees north and at longitude 73.32 decimal degrees west and is identified by the symbol  on the map.

(4): The simulated release occurred on Wednesday March 18, 2009 at 10:30 UTC.

(5) through (24): Same as what is defined in section 4.

Figure 2 shows the 24-hour time integrated surface to 500 m layer concentration for the period ending 24 hours after the time for which the initial data is available for the NWP model run. In this case, the 24-hour period ends on 19 March at 00 UTC and covers the period from 18 March 00 UTC to 19 March 00 UTC.

Figure 3 shows the 24-hour time integrated surface to 500 m layer concentration for the period ending 48 hours after the time for which the initial data is available for the NWP model run. In this case, the 24-hour period ends on 20 March at 00 UTC and covers the period from 19 March 00 UTC to 20 March 00 UTC.

Figure 4 shows the 24-hour time integrated surface to 500 m layer concentration for the period ending 72 hours after the time for which the initial data is available for the NWP model run. In this case, the 24-hour period ends on 21 March at 00 UTC and covers the period from 20 March 00 UTC to 21 March 00 UTC.

Note that the concentration contours sets in figure 2, 3 and 4 are different from each other.



Figure 5 shows the total (wet and dry) deposition in 24 hours for the period ending 24 hours after the time for which the initial data is available for the NWP model run. In this case, the 24-hour period ends on 19 March at 00 UTC and covers the period from 18 March 00 UTC to 19 March 00 UTC.

Figure 6 shows the total (wet and dry) deposition in 48 hours for the period ending 48 hours after the time for which the initial data is available for the NWP model run. In this case, the 48-hour period covers the period from 18 March 00 UTC to 20 March 00 UTC.

Figure 7 shows the total (wet and dry) deposition in 72 hours for the period ending 72 hours after the time for which the initial data is available for the NWP model run. In this case, the 72-hour period covers from 18 March 00 UTC to 21 March 00 UTC.

Finally, **Figure 8** shows the three dimensional trajectories starting at 10 UTC on 18 March at heights AGL of 500 metres, 1500 meters and 3000 metres above the source. The forecast trajectories end on 22 March 09 UTC.

6. Other products available from RSMC Montréal

Various additional products can be produced and distributed by RSMC Montréal if the situation requires it. These products go beyond the scope of this document and are not described here. However, they may be included in subsequent versions. For additional information, please contact RSMC Montréal directly.

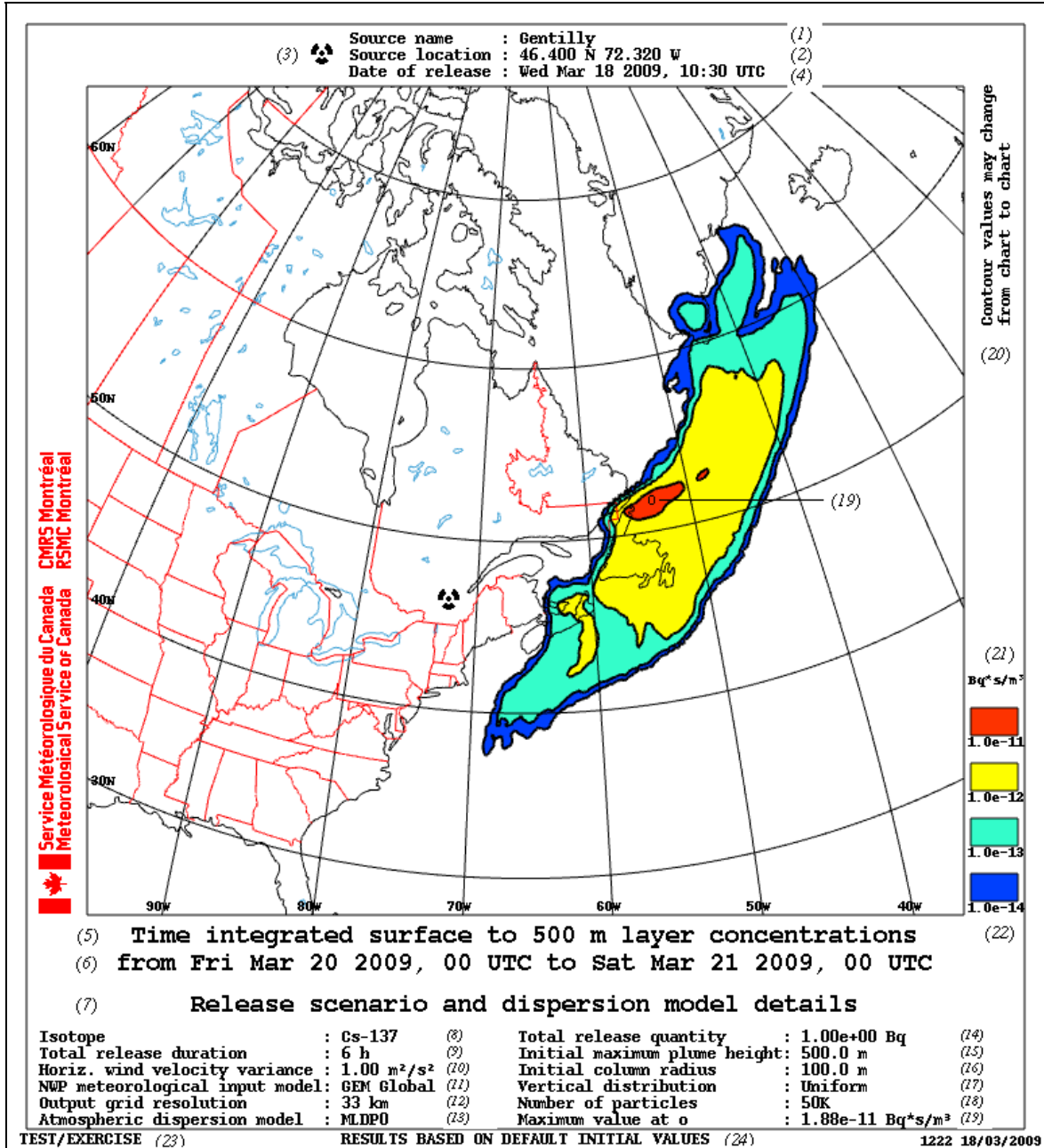


Figure 1

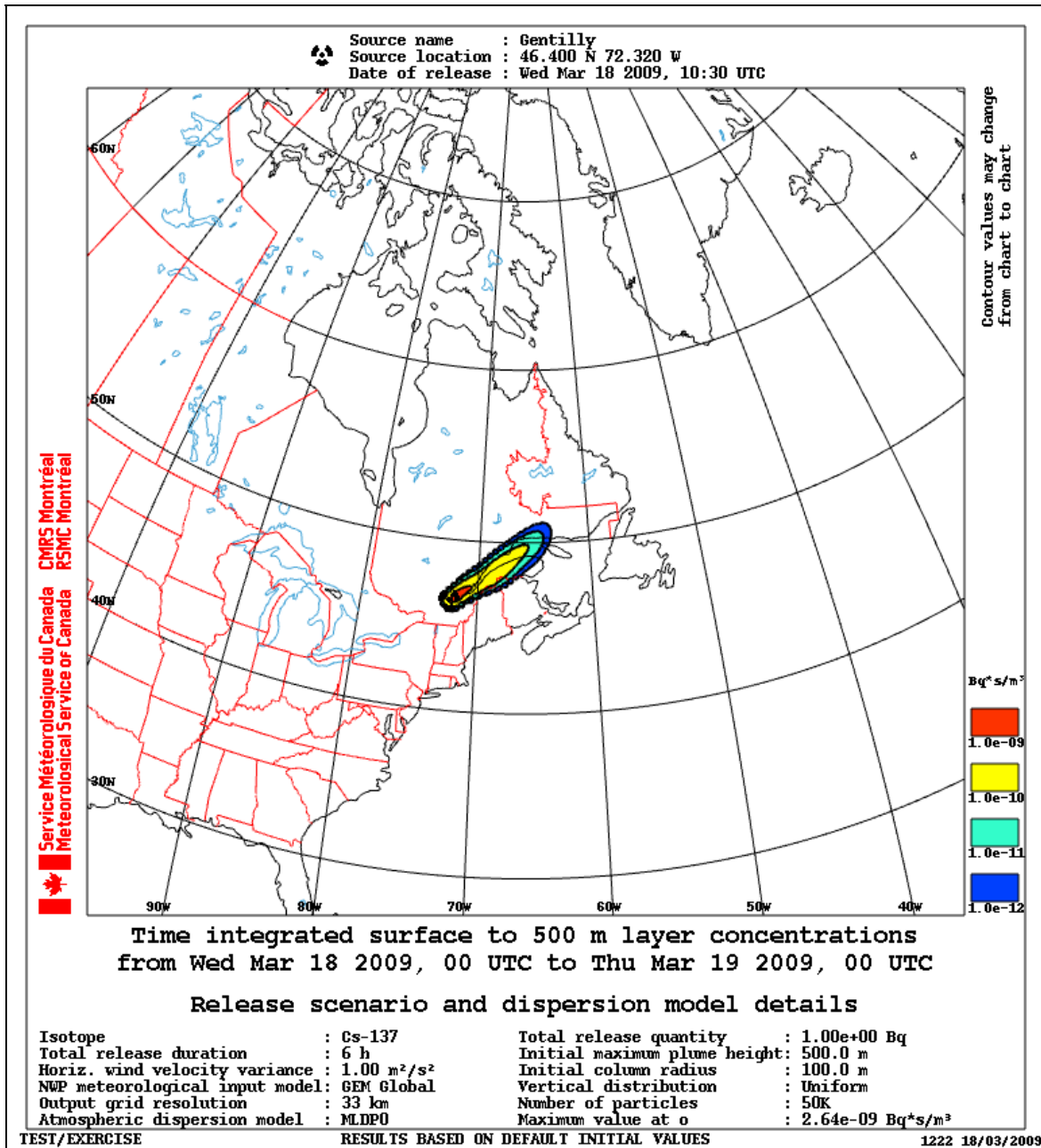


Figure 2

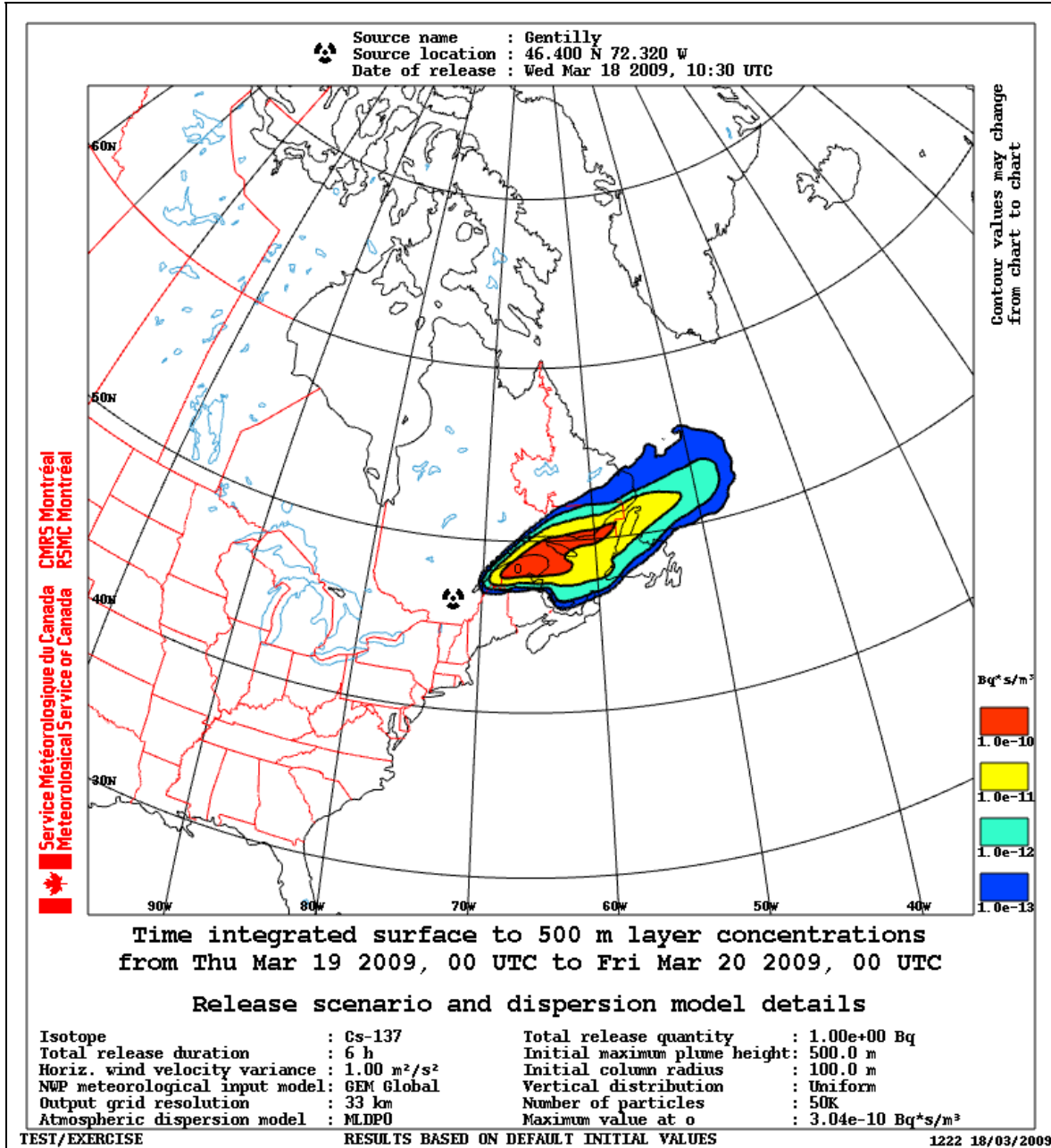


Figure 3

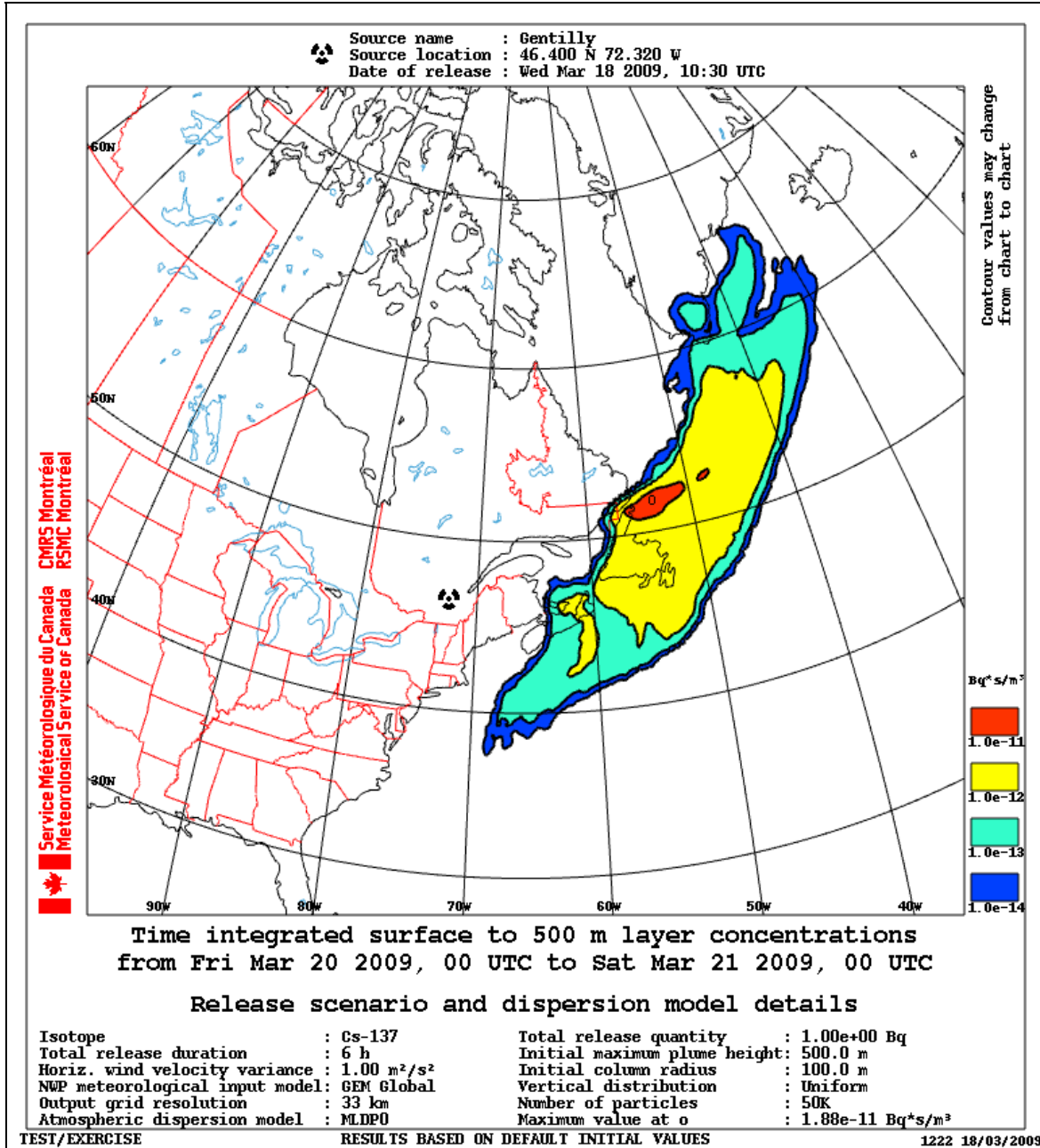


Figure 4

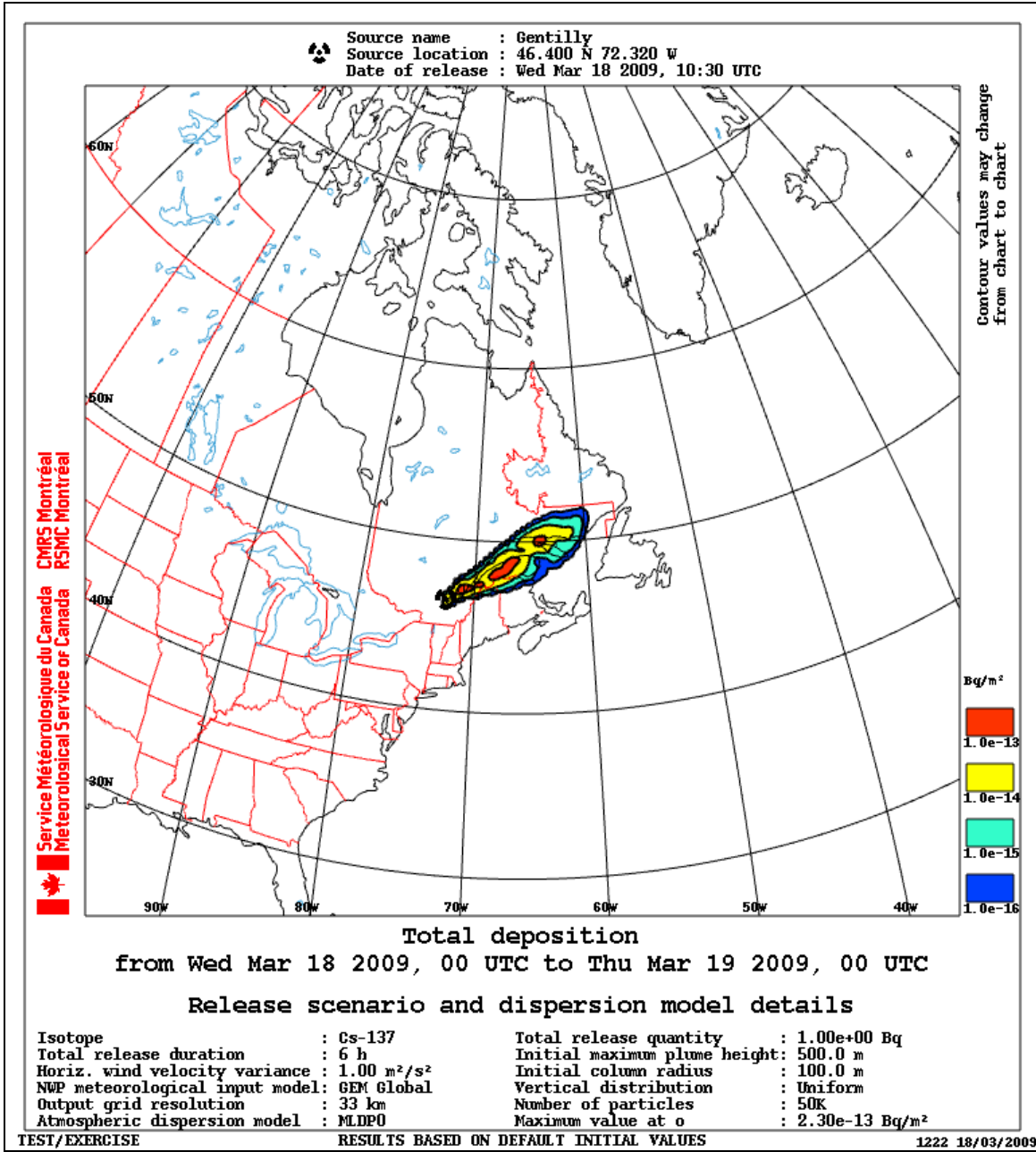


Figure 5

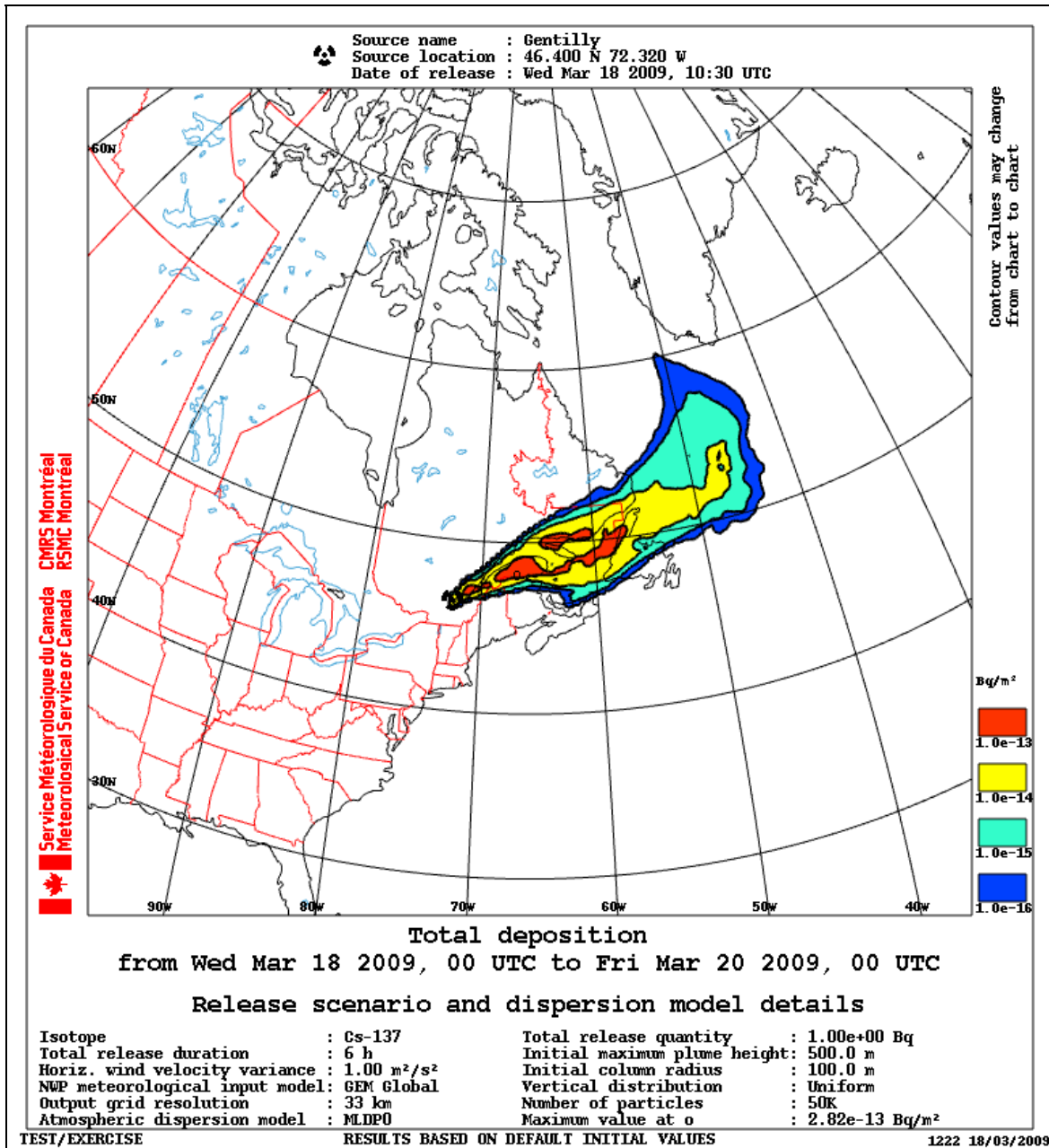


Figure 6

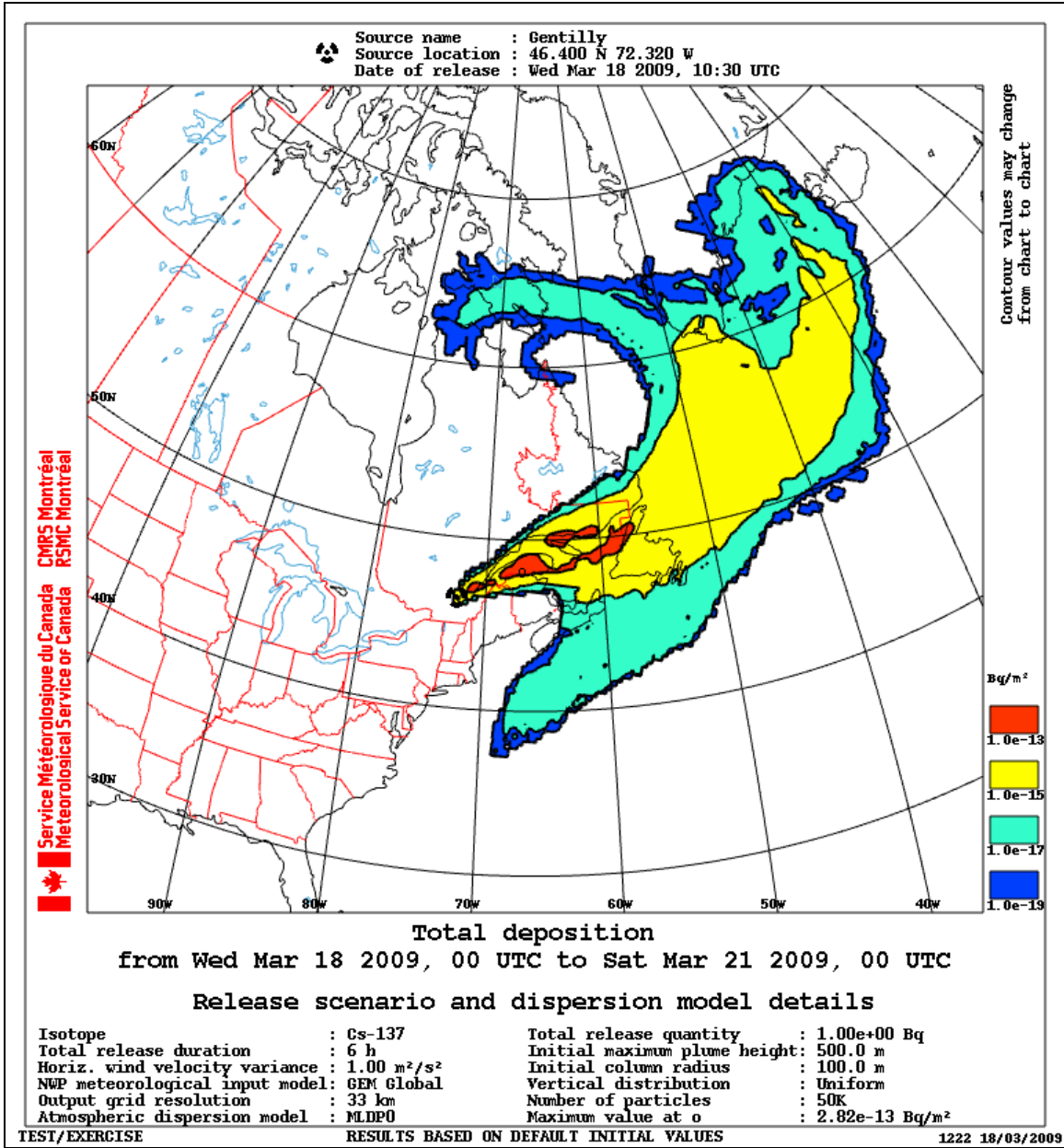


Figure 7

