RSMC MONTRÉAL
USERS' INTERPRETATION GUIDELINES FOR ATMOSPHERIC TRANSPORT MODEL OUTPUTS

Version 13

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

Environment and Climate Change Canada

Dorval, Québec, Canada

September 2018

1. Introduction

The Canadian Meteorological Centre (Meteorological Service of Canada, Environment and Climate Change Canada) is designated as the Montréal Regional Specialized Meteorological Centre (RSMC) by the WMO for the provision of atmospheric transport modelling in case of an environmental Emergency Response. The primary regions of responsibility (regional associations) are WMO RA-III & IV. These RA's include 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 a major component of the Meteorological Service of Canada, within Environment and Climate Change Canada. CMC is Canada's national meteorological centre, in constant operation, providing a variety of essential numerical weather prediction (NWP) products and services to national and international users. It operates one of the largest supercomputing centres in the country, and it supports national telecommunications networks and facilities as well as the national climate archives.

At CMC, Research and Development personnel work closely with the Centre's Operations Branch to ensure that the operational NWP systems are at the leading-edge of science and technology. CMC runs its operational suite of analysis and forecast models on a 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.

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 24/7 to lend additional support, such as in the event of an environmental emergency.

CMC's operational facilities enable a robust atmospheric transport and dispersion modeling capability. Current local, regional, and global weather conditions and forecasts are available to provide in real time the necessary input to the atmospheric transport and dispersion models and for their evaluation and interpretation. Archived data can be retrieved for simulations of recent and past events.

For NWP, the Global Environmental Multiscale (GEM) model is used by CMC operations (Côté et al., 1998). The GEM model is run several times per day in different configurations: global (Buehner et al., 2013, 2015; Charron et al., 2012), regional (Caron et al., 2015), and high-resolution (Mailhot et al., 2014). The global GEM configuration serves in the Ensemble Kalman Filter assimilation cycle, and for production of medium-to-long range forecast guidance. A comprehensive set of graphical and alphanumeric products is available from the different configurations of the GEM model. The higher resolution configurations of the GEM model provide shorter range forecast guidance.

GEM Model Configuration	**Acronym**	**Horizontal Resolution; Number of vertical levels**
Global	GDPS	25 km; 81
Regional	RDPS	10km; 81
High-resolution, National	HRDPS	2.5 km; 63
High-resolution, Arctic	CAPS	3.0 km; 63

Table 1: GEM model configurations

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 processes. The advection of an air parcel is calculated using a 4th-order Runge-Kutta numerical integration scheme. The model can be run either forward or backward in time.

The model estimates the trajectories of the parcels, originating from (or arriving at) a specified geographic location, starting (or ending) at different vertical levels. The location and vertical levels are specified 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 for a back trajectory) is specified as the input parameter.

MLDP (*Modèle Lagrangien de Dispersion de Particules*) is a fully 3-D Lagrangian particle dispersion model for medium and long range transport of pollutants in the atmosphere (D'Amours et al., 2015 and D'Amours and Malo, 2004). The model operator can choose between two vertical diffusion schemes: **order one** for applications at short distance scales, and **order zero** for larger scales. In MLDP, dispersion is modelled by calculating the trajectories of a large number of air particles (or parcels). The trajectory calculations are done in two parts:

1. 3-D displacements due to the transport by the non-turbulent component of the wind that is provided by the NWP system;
2. 3-D displacements due to turbulent motions that are unresolved by the NWP.

The horizontal component of diffusion (lateral mixing) is modeled by means of a Langevin stochastic equation that calculates turbulent components of the horizontal wind. In the order one configuration of MLDP, this is also applied to the vertical turbulent diffusion. The fluctuating components of the turbulent wind are obtained by partitioning the Turbulent Kinetic Energy (TKE) calculated in the driving NWP models.

In the order zero configuration, turbulent vertical mixing is parameterized by a random displacement equation, using a diffusion coefficient that is calculated from a mixing length, stability function, and vertical wind shear.

MLDP is an off-line model and uses full 3-D meteorological fields provided by an NWP system. Specifically, MLDP requires fields of wind, moisture, temperature and geopotential heights. These fields are obtained from the GEM operational data assimilation and forecast system, at either global, regional, or high resolution.

The modelled source term is input using an emission scenario module that can handle variable emission rates of several radionuclides.

In MLDP, it is assumed that the Lagrangian particles each represent a certain amount of tracer material. The concentration within a specified sampling volume for a given time interval is obtained by calculating the residence time of particles within that volume, during the time interval, weighted by the amount of material "carried" by the particles. The Lagrangian model is expected to give more accurate estimates of concentrations near the source, compared to an Eulerian model. Furthermore, the order one diffusion scheme is expected to give more accurate concentrations near the source, compared to the zero order scheme.

Dry deposition in MLDP is parameterized using a deposition velocity and an absorption probability. The deposition rate is calculated by assuming that when a particle moves into the layer adjacent to the ground surface, it contributes to the total surface deposition flux in proportion to the amount of tracer material it represents.

Wet deposition in MLDP is modelled with a simple wet scavenging rate scheme applied when a particle is presumed to be in a cloud. The precipitation field is not used directly in MLDP, but the tracer wet scavenging rate is proportional to the local cloud fraction and the amount of material carried by the particle. Local cloud fraction is itself parameterized as a function of relative humidity. A more sophisticated physical parameterization of precipitation scavenging (Feng, 2007) can be activated when NWP precipitation rate fields are available.

The MLDP code is parallelized and can be executed on several nodes on CMC's supercomputer or on Linux clusters. It uses both distributed and shared-memory standards. Distributed-memory parallelism is implemented with MPI (Message Passing Interface) library while shared-memory parallelism relies on OMP (Open Multi-Processing) directives.

The model can calculate outputs on various types of grid, such as polar stereographic and cylindrical equidistant (lat-long) grids, in either northern or southern hemisphere. Available horizontal grid resolutions range from 50 km, for hemispheric coverage, down to 100 m for local coverage. A global lat-long configuration also exists at horizontal resolutions of 1°, 0.5°, or 0.25°.

The vertical discretization in MLDP uses GEM model ETA levels that span the troposphere and lower stratosphere.

MLDP can also be executed in adjoint-backward mode for inverse modelling applications. The model has been used extensively in this configuration to provide guidance to the CTBTO-PTS as part of the treaty verification programme.

MLDP has been used for several types of applications:

- Long range simulations (>100 km, up to ~10^4 km)
- Medium range simulations (from 10 to 100 km)
- Complex meteorological conditions & topography
- Volcanic eruptions
- Nuclear accident (multiple radionuclides)
- Biohazards (e.g. foot-and-mouth disease, avian flu, Legionnaires' disease)
- Toxic material fire, chemical release, forest fire, sand or dust storm

Operationally, MLDP uses meteorological fields provided by the CMC forecast and analysis system. This data can be used in either diagnostic or forecast mode, or a combination of both. For diagnostic mode, a few weeks of past weather analyses are kept on-line, enabling fast access. For cases further back in time, data can be retrieved from archives. In forecast mode, data from the most recent 00 UTC and 12 UTC global GEM forecasts extend to 240 hours. The higher resolution models starting at 00, 06, 12, and 18 UTC produce forecasts out to 2 or 3 days.

MLDP is fully integrated into the operations of the CMC. An MLDP simulation can be requested at any time by the duty meteorologist.

References

Côté, J., Desmarais, J.-G., Gravel, S., Méthot, A., Patoine, A., Roch, M., Staniforth, A., 1998, “The operational CMC–MRB Global Environmental Multiscale (GEM) model. Part II: results”, *Monthly Weather Review*, **126** (6), 1397–1418, doi:10.1175/1520-0493(1998)126<1397:TOCMGE>2.0.CO;2.

Buehner, M., McTaggart-Cowan, R., Beaulne, A., Charette, C., Garand, L., Heilliette, S., Lapalme, E., Laroche, S., Macpherson, S.R., Morneau, J., Zadra, A., 2015, Implementation of Deterministic Weather Forecasting Systems Based on Ensemble-Variational data Assimilation at Environment Canada. Part I: The Global System, *Monthly Weather Review*, **143** (7), 2532–2559, doi:10.1175/MWR-D-14-00354.1.

Buehner, M., Morneau, J., Charette, C., 2013, “Four-dimensional ensemble-variational data assimilation for global deterministic weather prediction”, *Nonlinear Processes in Geophysics*, **20** (5), 669–682, doi:10.5194/npg-20-669-2013.

Caron, J.-F., Milewski, T., Buehner, M., Fillion, L., Reszka, M., Macpherson, S., St-James, J., 2015, “Implementation of Deterministic Weather Forecasting Systems Based on Ensemble-Variational Data Assimilation at Environment Canada. Part II: The Regional System”, *Monthly Weather Review*, **143** (7), 2560–2580, doi:10.1175/MWR-D-14-00353.1.

Charron, M., Polavarapu, S., Buehner, M., Vaillancourt, P.A., Charette, C., Roch, M., Morneau, J., Garand, L., Aparicio, J.M., MacPherson, S., Pellerin, S., St-James, J., Heilliette, S., 2012, “The Stratospheric Extension of the Canadian Global Deterministic Medium-Range Weather Forecasting System and Its Impact on Tropospheric Forecasts”, *Monthly Weather Review*, **140** (6), 1924–1944, doi:10.1175/MWR-D-11-00097.1.

D’Amours, R., Malo, A., Flesch, T., Wilson, J., Gauthier J.-P., Servranckx, R., 2015, “The Canadian Meteorological Centre's Atmospheric Transport and Dispersion Modelling Suite”, *Atmosphere-Ocean*, **53** (2), 176–199, doi:10.1080/07055900.2014.1000260

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

Feng, J., 2007, A 3-mode parametrization of below-cloud scavenging of aerosols for use in atmospheric dispersion models, *Atmosphere-Ocean*, **41** (32), 6808-6822.

Mailhot, J., Milbrandt, J. A., Giguère, A., McTaggart-Cowan, R., Erfani, A., Denis, B., Glazer, A., Vallée, M., 2014, An Experimental High-Resolution Forecast System During the Vancouver 2010 Winter Olympic and Paralympic Games, *Pure and Applied Geophysics*, **171** (1), 209–229, doi:10.1007/s00024-012-0520-6.

Mastin, L. G., Guffanti, M., Servranckx, R., Webley, P., Barsotti, S., Dean, K., Durant, A., Ewert, J.W., Neri, A., Rose, W.I., Schneider, D., Siebert, L., Stunder, B., Swanson, G., Tupper, A., Volentik, A., Waythomas, C. F., 2009, "A multidisciplinary effort to assign realistic source parameters to models of volcanic ash-cloud transport and dispersion during eruptions", *Journal of Volcanology and Geothermal Research*, **186** (1-2), 10–21, doi:10.1016/j.jvolgeores.2009.01.008.

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 MLDP output maps for a hypothetical emission scenario

Figure 1 presents a labelled output map as obtained from an MLDP forecast using a hypothetical 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)*: Date of release:** Identifies the date (month, day and year) and start time (hour and minute UTC) of the release.

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

(5): Identification of the field that is plotted on the map. 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 starts at the beginning of the emission and ends at either 12 UTC or 24 UTC. As a result, the time elapsed from the release to the end of the period will be 24 hours or less. For example, if the release starts 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).*

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

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

***(8)*: Isotope:** Indicates the radionuclide used in the modelling. The default radionuclide is Caesium 137 (^{137}Cs, half-life 30.17 years).

***(9)*: Total release duration:** Time elapsed between the start and the end of the emission. The default release duration is 6 hours.

(10)**: Horizontal wind velocity variance:** This parameter serves to model mesoscale fluctuations within the boundary layer and in the free atmosphere. The default value is 1 m^2/s^2.

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

(12)**: Output grid resolution:** The horizontal spacing, in km, of the grid on which the dispersion model outputs the calculated concentration and deposition fields. The default output horizontal grid resolution is 33 km.

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

(14)**: Total release quantity:** Total quantity of the radionuclide involved in the simulation. This amount is expressed in terms 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 above ground level (AGL).

(16)**: Initial column radius:** Indicates the initial horizontal radius of the emission column. The default value 100 m.

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

(18)**: Number of particles:** Indicates the number of Lagrangian particles released from the source associated with the selected radionuclide. The default number of particles is 50000.

(19)**: Maximum value at ★ :** A star (★) indicates the location on the map of the maximum value. Units are [$Bq \cdot s/m^3$] for the 24-hour time integrated concentrations and [Bq/m^2] for total deposition. If the maximum concentration is near the source, the star may be covered by the symbol ☢ that indicates the source location.

(20)**: Contour values may change from chart to chart:** This message is repeated on each map to alert the user that contour values may vary from chart to chart.

(21)**: Units corresponding to items *(5)* and *(22)*:** [$Bq \cdot s/m^3$] 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 indications are **REQUESTED SERVICES, IAEA NOTIFIED EMERGENCY** and **TEST/EXERCISE** (default notification)**.**

(24)**: Date-time of the production of the chart (HHMM dd/mm/yyyy)**.

5. Complete set of MLDP output maps for a hypothetical scenario

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

(1)**:** The hypothetical source is Whiteshell (Manitoba, Canada).

(2), (3)**:** The location is latitude 50.179764 decimal degrees north, longitude 96.060067 decimal degrees west, and is identified by the symbol ☢ on the map.

(4)**:** The simulated release occurred on Tuesday July 25, 2017 at 00:00 UTC.

(5) through ***(24)*****:** As 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 start time of the NWP model run. In this example, the 24-hour period covers the period from 25 July 00 UTC to 26 July 00 UTC.

Figure 3 shows the 24-hour time integrated surface to 500 m layer concentration for the period ending 48 hours after the start time of the NWP model run. In this example, the 24-hour period covers the period from 26 July 00 UTC to 27 July 00 UTC.

Figure 4 shows the 24-hour time integrated surface to 500 m layer concentration for the period ending 72 hours after the start time of the NWP model run. In this example, the 24-hour period covers the period from 27 July 00 UTC to 28 July 00 UTC.

Figure 5 shows the total (wet and dry) deposition in 24 hours for the period ending 24 hours after the start time of the NWP model run. In this example, the 24-hour period covers the period from 25 July 00 UTC to 26 July 00 UTC.

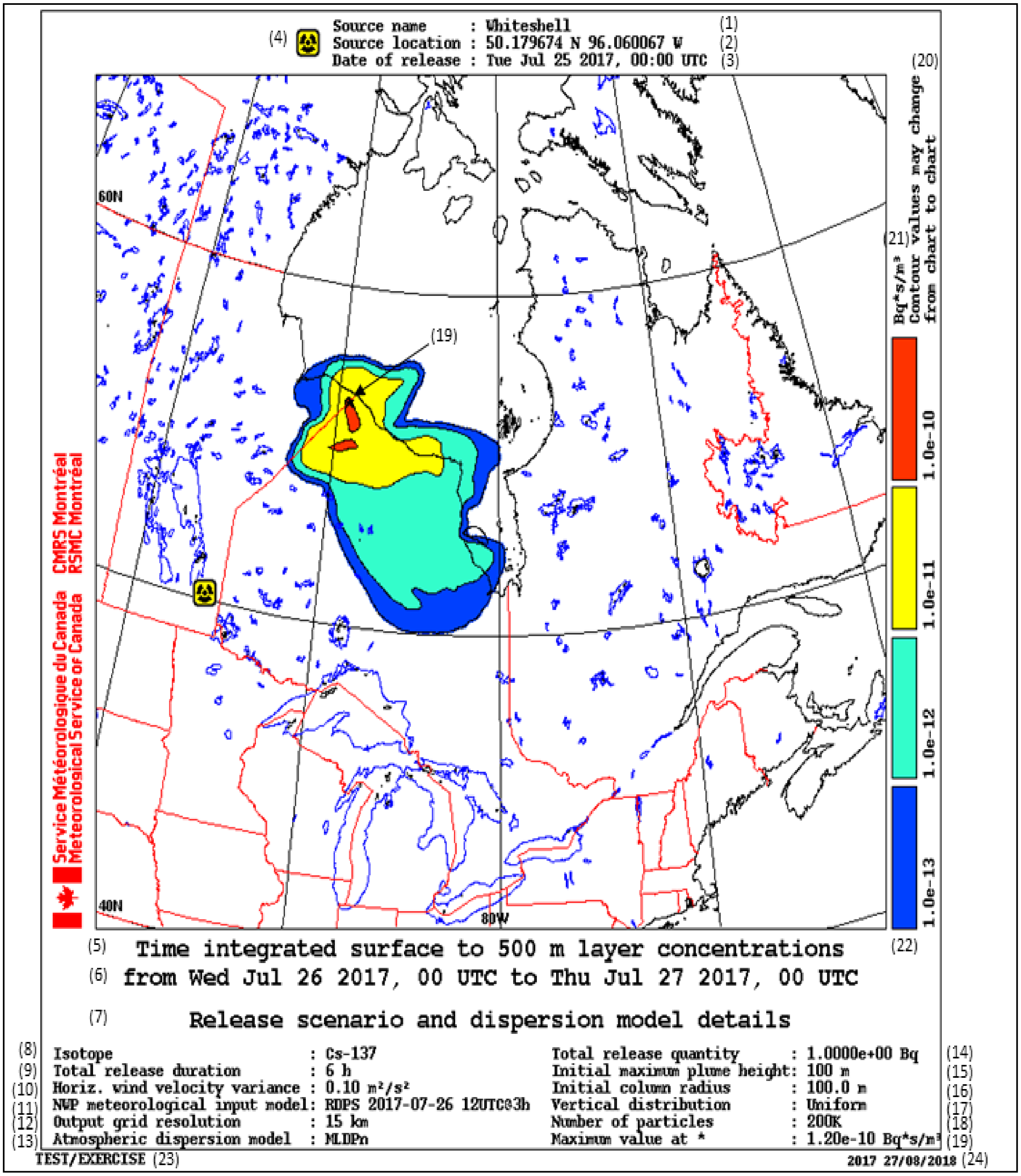
Figure 6 shows the total (wet and dry) deposition in 48 hours for the period ending 48 hours after the start of the NWP model run. In this example, the 48-hour period covers the period from 25 July 00 UTC to 27 July 00 UTC.

Figure 7 shows the total (wet and dry) deposition in 72 hours for the period ending 72 hours after the start time of the NWP model run. In this example, the 72-hour period covers the period from 25 July 00 UTC to 28 July 00 UTC.

Figure 8 shows the three-dimensional trajectories of particles released at 00 UTC on 25 July at heights of 500 metres, 1500 metres, and 3000 metres AGL above the source. The forecast trajectories end on 28 July 00 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. For additional information, please contact RSMC Montréal directly.



Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Time integrated surface to 500 m layer concentrations
from Wed Jul 26 2017, 00 UTC to Thu Jul 27 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m²/s²
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn

Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 1.20e-10 Bq*s/m³

TEST/EXERCISE
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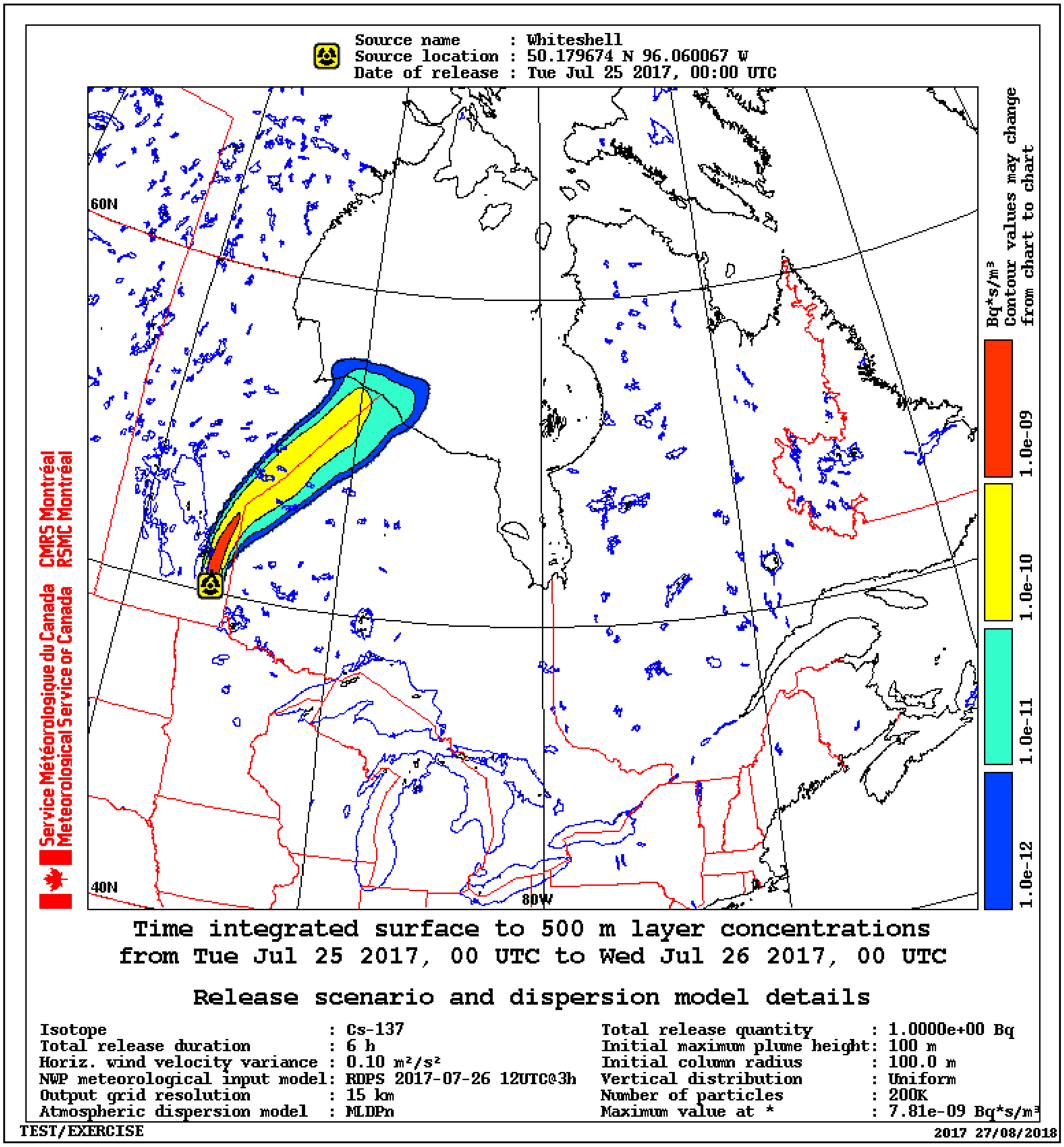
Figure 1



Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Time integrated surface to 500 m layer concentrations
from Tue Jul 25 2017, 00 UTC to Wed Jul 26 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m²/s²
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn

Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 7.81e-09 Bq*s/m³

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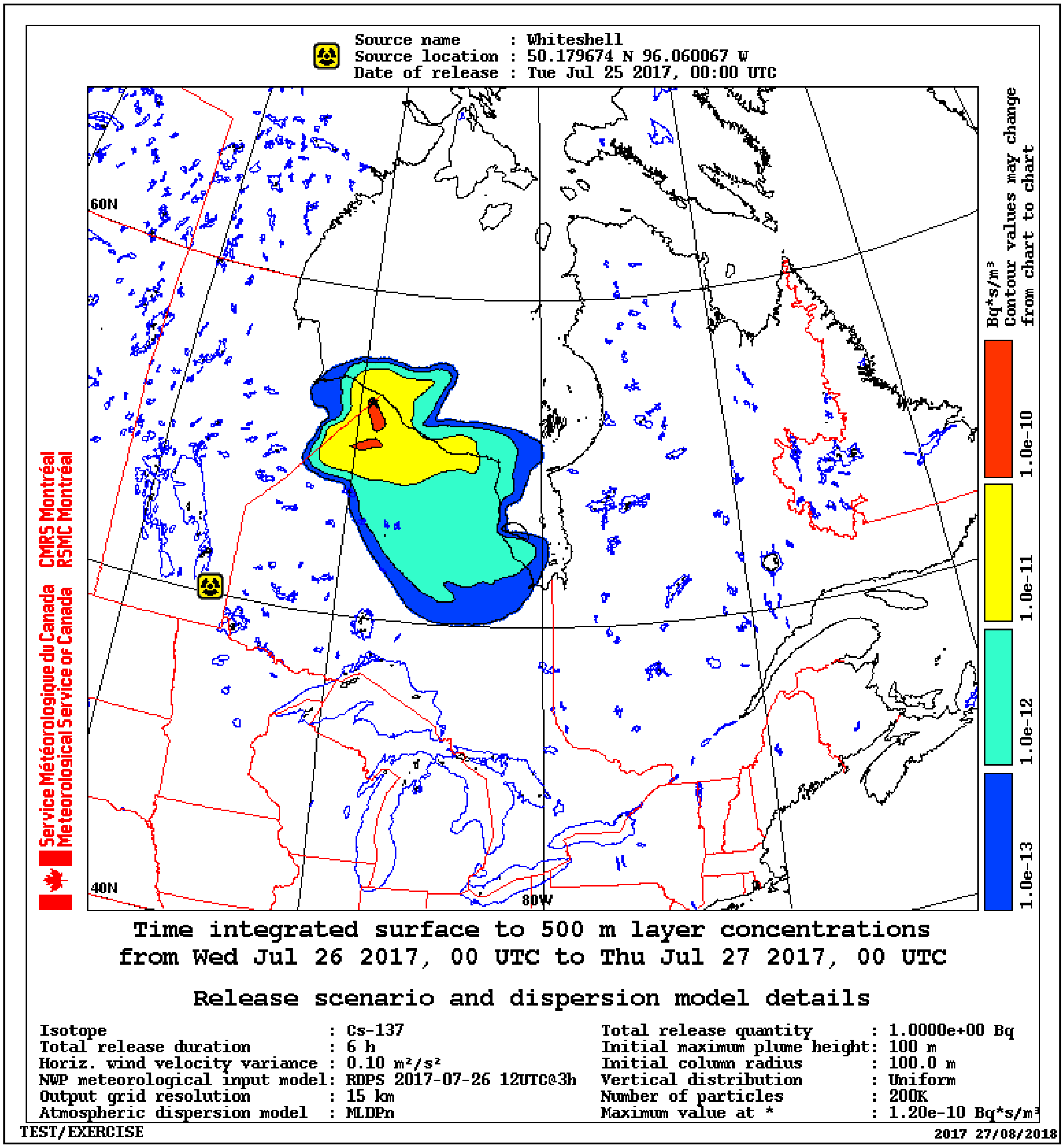
Figure 2



Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Time integrated surface to 500 m layer concentrations
from Wed Jul 26 2017, 00 UTC to Thu Jul 27 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m²/s²
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn

Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 1.20e-10 Bq*s/m³

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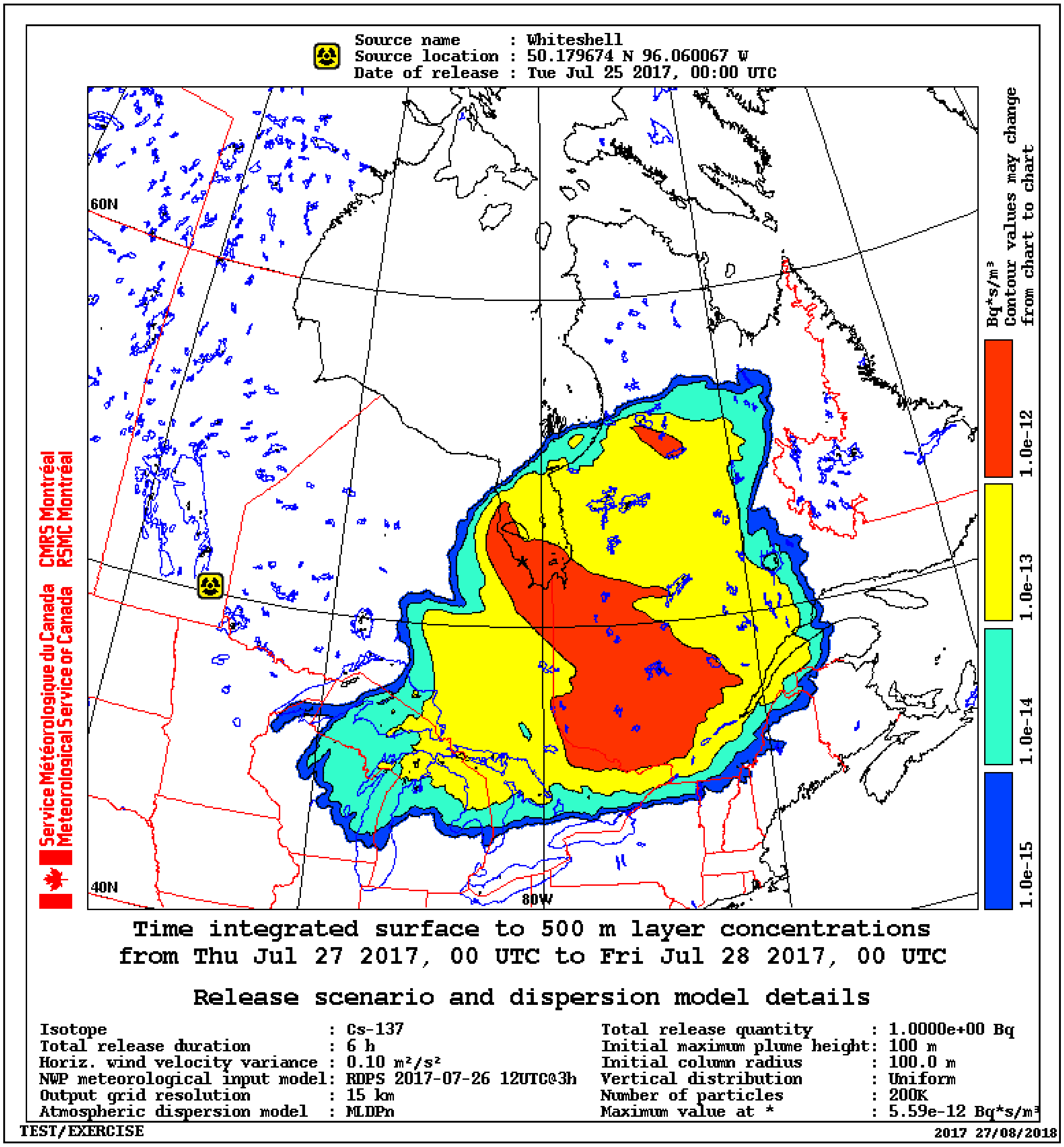
Figure 3


Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Time integrated surface to 500 m layer concentrations
from Thu Jul 27 2017, 00 UTC to Fri Jul 28 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m²/s²
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn
Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 5.59e-12 Bq*s/m³

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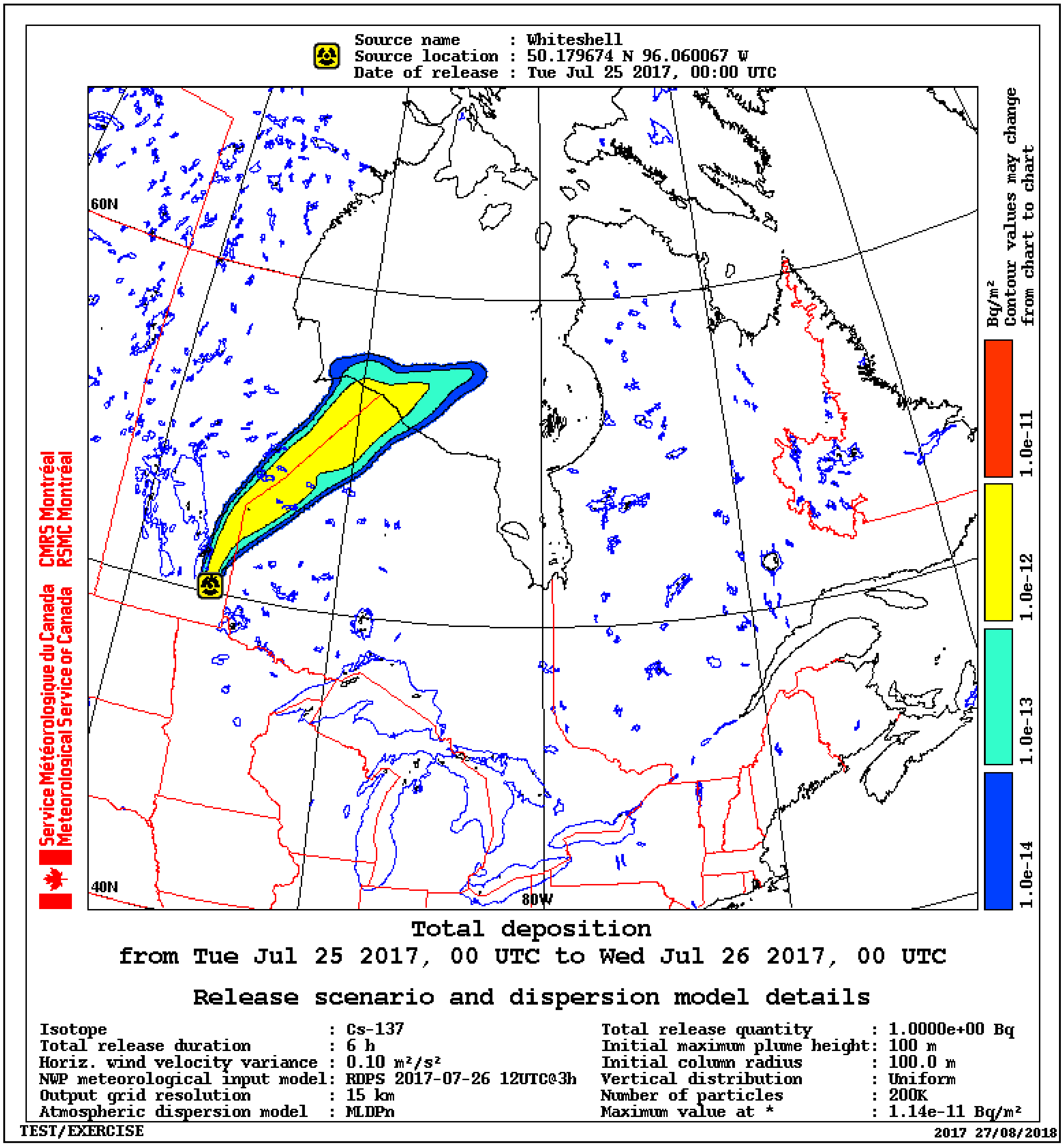
Figure 4



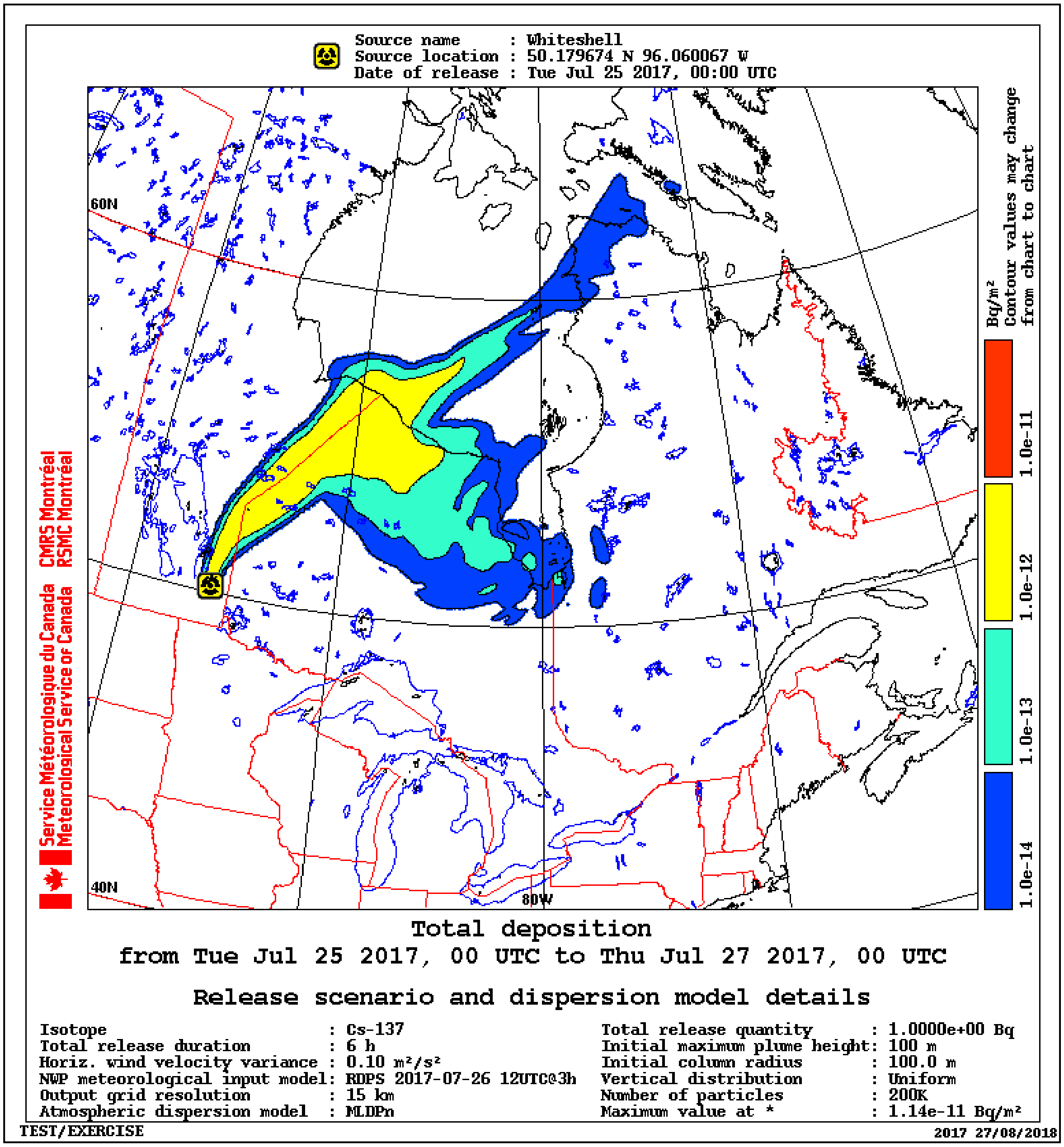
Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Total deposition
from Tue Jul 25 2017, 00 UTC to Wed Jul 26 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m^2/s^2
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn
Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 1.14e-11 Bq/m^2

Figure 5



Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Total deposition
from Tue Jul 25 2017, 00 UTC to Thu Jul 27 2017, 00 UTC

Release scenario and dispersion model details

Isotope : Cs-137
Total release duration : 6 h
Horiz. wind velocity variance : 0.10 m²/s²
NWP meteorological input model: RDPS 2017-07-26 12UTC@3h
Output grid resolution : 15 km
Atmospheric dispersion model : MLDPn

Total release quantity : 1.0000e+00 Bq
Initial maximum plume height: 100 m
Initial column radius : 100.0 m
Vertical distribution : Uniform
Number of particles : 200K
Maximum value at * : 1.14e-11 Bq/m²

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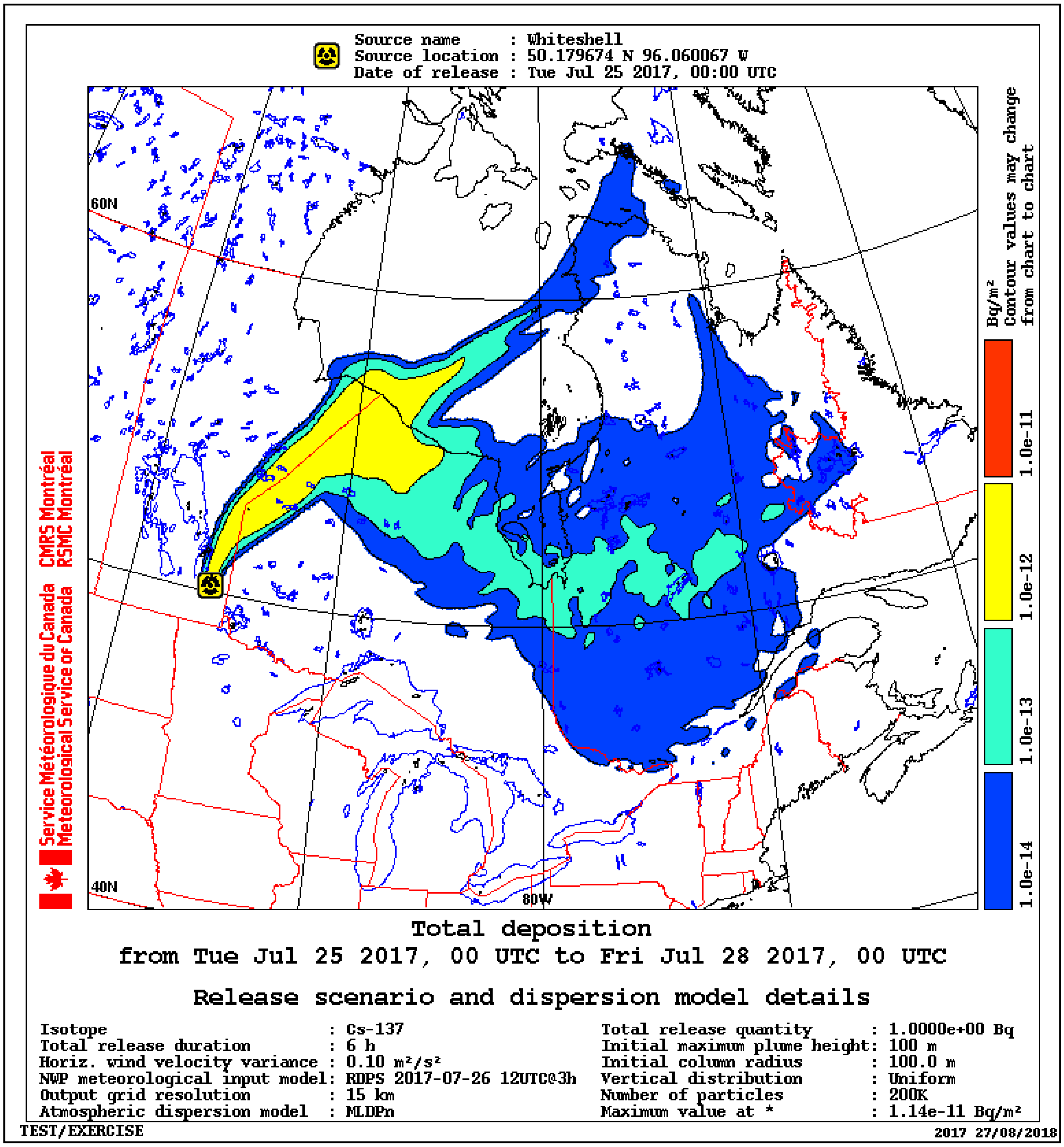
Figure 6



Source name : Whiteshell
Source location : 50.179674 N 96.060067 W
Date of release : Tue Jul 25 2017, 00:00 UTC

Total deposition
from Tue Jul 25 2017, 00 UTC to Fri Jul 28 2017, 00 UTC

Release scenario and dispersion model details

Isotope	Cs-137	Total release quantity	1.0000e+00 Bq
Total release duration	6 h	Initial maximum plume height	100 m
Horiz. wind velocity variance	0.10 m²/s²	Initial column radius	100.0 m
NWP meteorological input model	RDPS 2017-07-26 12UTC@3h	Vertical distribution	Uniform
Output grid resolution	15 km	Number of particles	200K
Atmospheric dispersion model	MLDPn	Maximum value at *	1.14e-11 Bq/m²

TEST/EXERCISE

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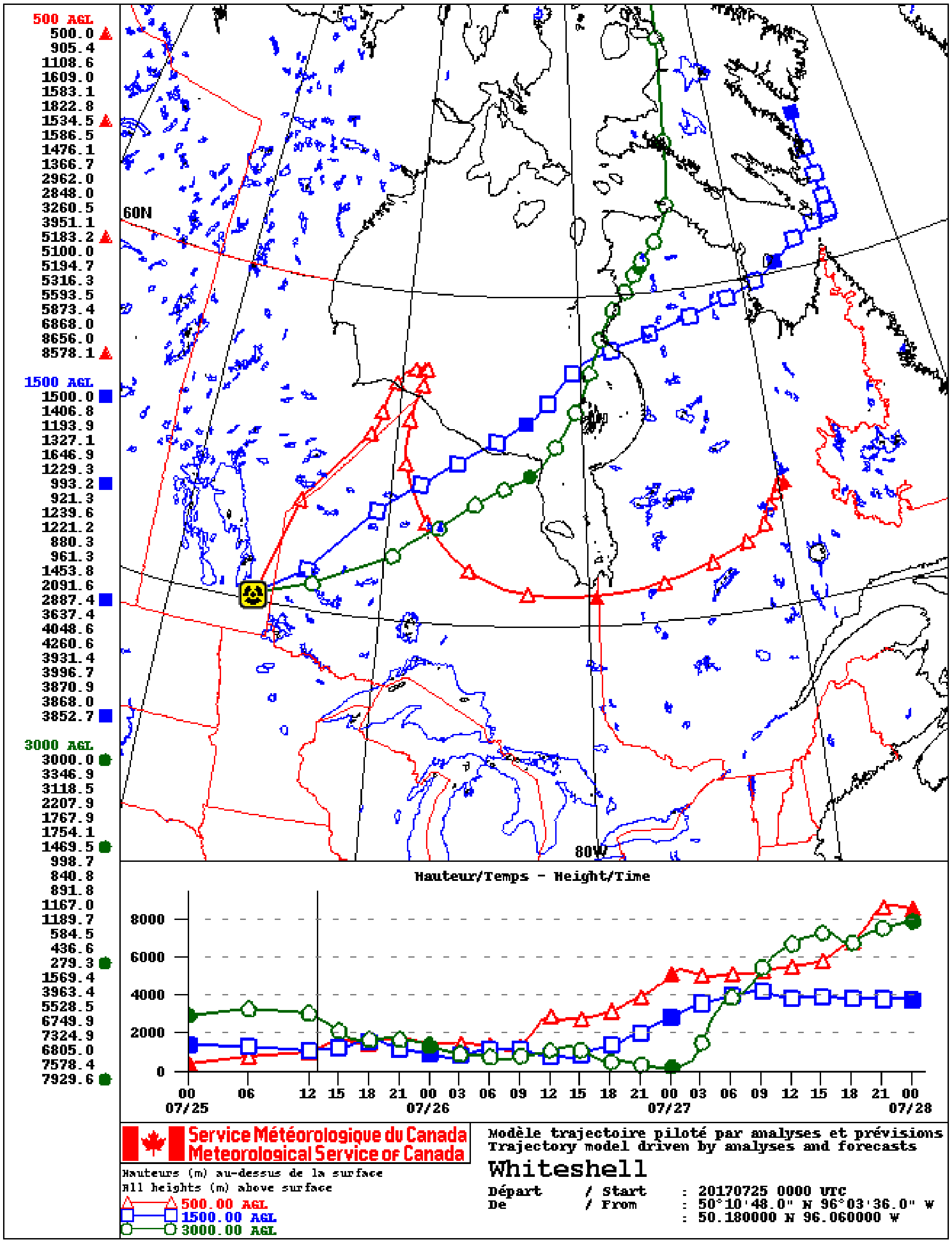
Figure 7



TEST/EXERCISE

2015 27/08/2018

Figure 8