METEO FRANCE
Toujours un temps d'avance

RSMC TOULOUSE
USERS'INTERPRETATION GUIDELINES
ATMOSPHERIC TRANSPORT MODEL OUTPUTS

February 2010

Important note : The model MOCAGE-accident replaced the model MEDIA in February 2010 as the operational model of RSMC Toulouse for atmospheric transport and dispersion. MEDIA is no longer used but will be still available during a few months as a backup.

1. Introduction

Météo-France is a French executive agency with legal status and financial autonomy. Its responsibilities towards the state, the economic agents and the people cover all services concerning the atmosphere and surface of the ocean. This includes observation, forecasting, climatology, research and service to users. Météo-France must fulfil international commitments in the field of aviation and marine meteorology. With its overseas territories, France is present in 5 of the 6 WMO regions. In particular, the overseas centre of La Réunion is a Regional Specialized Meteorological Centre (RSMC) for cyclones in the Indian ocean.

Meteo-France has also international responsibilities for environmental emergencies: the National Forecasting Centre "CNP" (Centre National de Prévision, Météo-France) is designated as the Toulouse RSMC by the WMO for the provision of atmospheric transport model outputs in case of an environmental Emergency Response. The primary regions of responsibility (Regional Associations) are WMO RA-I & VI: Africa and Europe. This document provides a description of RSMC Toulouse modelling tools and products.

2. The french National Centre for Meteorological Forecasts (CNP)

The CNP operates a complete numerical weather prediction system, provides a large variety of products elaborated by experienced meteorologists working 24/7 around the clock, and disseminates them to national and international users.

In case of an international environmental emergency, as for a national one, Météo-France organises a dedicated Meteorological Crisis operations Centre (CMC) to provide continuously updated information about pollutant release, transport and deposition. Activated under the authority of the Head of the Forecast Division, the CMC gathers several people (the Head of Forecast Division himself or its deputy, the forecaster in chief, a technical secretary, and experts if needed). The CMC operates the Atmospheric Transport Model (ATM) and collects information related to the event from the GTS (meteorological observations or information concerning the evolution of the incident). The CMC is in charge of interpreting ATM products, meteorological fields as well as pollutants distributions, in order to prepare relevant comments on the situation.

Météo-France operational suite of NWP models and ATMs runs on central computing facilities. Model outputs can be visualized and combined with other meteorological data on powerful Linux systems to be interpreted by experienced forecasters. Finally, elaborated products including messages or graphical data can be sent by internet (website or email) or traditional means like fax or dedicated and RTC lines.

3. Atmospheric transport and dispersion modelling

3.1 The air mass trajectory tool

The air mass trajectory tool computes simple lagrangian trajectories. Three neutrally buoyant particles are released in the atmosphere at a geographic location defined by the user and at three fixed vertical levels: 950, 850 and 700 hPa, corresponding to about 500, 1500 and 3000 m above sea level in standard atmosphere. The particles are only subjected to the action of the large-scale wind ; no other physical or atmospheric process is taken into account. The 3-D wind field is provided by the global NWP models ARPEGE from Météo-France or IFS from ECMWF (choice of the user) sampled at 0.5° resolution and on 15 vertical pressure levels, from 1000 to 100 hPa. The tool provides a quick estimate of the expected trajectory of air parcels originating from the planetary boundary layer at the location of interest.

3.2 The MOCAGE-accident model

MOCAGE-accident is based upon the MOCAGE[1] three-dimensional chemistry and transport model developed by Météo-France. From air quality forecasting to the study of interactions between climate and chemistry, MOCAGE is a flexible tool that is currently used for both research on atmospheric composition (over 40 publications in the international literature) and operations in Météo-France and at several collaborating institutes. In particular, MOCAGE products are used for the French operational Air Quality platform Prév'Air (http://www.prevair.org) as well as in projects building up the Global Monitoring for Environment and Security (GMES) Atmospheric Service.

[1] Modèle de Chimie Atmosphérique à Grande Echelle: model for atmospheric chemistry at large scales

MOCAGE considers simultaneously the troposphere and the stratosphere at the planetary scale; in addition, it is possible within the model to zoom down to the regional scale over limited-area sub-domains, the model providing its own time-dependent chemical boundary conditions.
Depending upon applications, MOCAGE can run in both on-line, coupled to a general circulation model for climate studies for instance, or off-line modes, forced by archived meteorological analyses or forecasts.
MOCAGE is based upon a semi-lagrangian advection scheme (Williamson and Rasch, 1989), using a cubic polynomial interpolation in all three directions. At the expense of a specific mass conservation correction (applied every time step), the semi-lagrangian formulation allows to treat simultaneously a large number of tracers, typically of the order of one hundred or more.
Concerning physical and chemical parameterizations, an operator splitting approach is used. Parameterizations are called alternatively in forward and reverse order, with the objective to reduce systematic errors. Several options of parameterizations are available within MOCAGE; options used in MOCAGE-accident are described hereafter.

MOCAGE-accident is a specific version of MOCAGE specifically tuned for the transport and diffusion of accidental release from the regional to the global scale. Only dynamical and physical processes are taken into account, excluding chemistry.

MOCAGE-accident runs in off-line mode, using Météo-France ARPEGE or ECMWF/IFS operational NWP products as dynamical forcings. Meteorological forcings (hydrostatic winds, temperature, humidity and pressure) feed the advection scheme, as well as the physical parameterizations. They are considered every 6 hours, and are linearly interpolated to yield hourly values, which is the time-step for advection; smaller time-steps are used for physical processes, but the meteorological variables are kept constant over each hour.

MOCAGE-accident can be run for an emission taking place everywhere over the globe. In the operational configuration, it has a 0.5° horizontal resolution and 47 hybrid (σ,P) levels from the surface up to 5 hPa, with approximately 7 levels in the planetary boundary layer, 20 in the free troposphere and 20 in the stratosphere. In this way, the model can consider emissions in the first meters above the surface as well as over thousands kilometres up to the stratosphere.

An external module allows the user to specify the temporal and geographical characteristics of the release, and information on the pollutant: nature, as well as emission rate if known but generally default values are prescribed. In the vertical, the emission rate is uniform. Three types of pollutants can be considered:

- Chemical pollutants are treated as tracers. No interactions between these pollutants and the other atmospheric components are considered; only transport, wet and dry deposition are taken into account.
- Radionuclides are treated as tracers except a radioactive decay is considered.
- Volcanic ashes: In this case, solid materials are considered. Sedimentation of the particles is taken into account in addition to processes represented for tracers. The

‘volcanic ashes’ option is used to forecast plumes of volcanic ashes in support of Météo-France responsibilities of the Toulouse Volcanic Ash Advisory Centre (VAAC).

As already stated, advection is performed in MOCAGE-accident with a semi-lagrangian advection scheme. Concerning parameterized transport:

– Turbulent mixing is treated following (Louis, 1979), as in the NWP suite ARPEGE/ALADIN. Horizontal diffusion is neglected, while the vertical diffusion coefficient K depends on height, wind shear and atmospheric stability. The more unstable the atmosphere, the greater K.
– Transport by convection is based on a mass flux scheme (Bechtold et al., 2001). Downdrafts are taken into account, as well as freezing and melting. All computations are one-dimensional. To trigger (or not) convection in a column, a mixed air parcel is lifted from the ground to its lifting condensation level. If the difference between its virtual temperature θ_v^{mix} and that of environment θ_v is sufficiently high, then convection can be triggered off. The ability of the parcel to produce sufficient cloud depth is added to this condition. Shallow convection shall give at least a 500m high cloud, and deep convection shall extend on 3 km. Fractional entrainment (ε_u) and detrainment (δ_u) rates are set constant. The thermodynamic characteristics of the updraft are computed assuming that, except from precipitation processes, enthalpy and total water mixing ratio are conserved. Finally, the intensity of the convection is controlled by a closure assumption. It is based on the removing of all Convective Available Potential Energy during an adjustment period, set to 3 hours for shallow convection and between 0.5 and 1 hour for deep convection.

Concerning physical parameterizations:

– Dry deposition is accounted for simply, using fixed deposition velocities.
– Wet deposition is treated with a detailed scheme which takes into account the convective part following (Mari, 2000) and the stratiform part following (Liu, 2001). The original feature of treatment for convective part is that convection and scavenging are considered simultaneously, and not successively; it allows a better representation of physical processes. Stratiform scavenging is applied over the whole vertical column, with possibly re-evaporation if needed.
– The treatment of radioactive decay takes into account the type of radionuclide and its lifetime.
– Sedimentation is simply treated with a settling velocity which depends on the size and density of the particle.

MOCAGE-accident can also be run in “inverse” mode in order to provide information on the origin of an air-mass arriving at a given point in space and time. This configuration is used to perform backtracking simulations in the context of Comprehensive Test Ban Treaty Organisation (CTBTO) requests to RSMC. It takes only into account semi-lagrangian backwards advection and eddy diffusion (auto-adjoint process).

4. Description of products

4.1 Description of MOCAGE-accident output maps for a hypothetical default scenario

The following figures present output maps from a MOCAGE-accident forecast based on a hypothetical scenario at the Golfech nuclear plant (France).

Figure 1 presents a description of all the information available on each output map. The labelled items are as follows:

(1) Source name, Simulation type (Accident / Exercise), Release date
(2) Product represented on the map (Time integrated concentration / Total deposition)
(3) Valid time of the product
(4) Origin of the meteorological fields used in the simulation (ARPEGE / ECMWF)
(5) If the simulation is based on a default scenario, "Results based on default initial values" is mentioned here.

Labels (6) to (14) describe the source characteristics:
(6) Source name
(7) Date and hour of the beginning of the pollutant release
(8) Release duration
(9) Latitude of the source
(10) Longitude of the source
(11) Emission rate (with unit)
(12) Base height of the vertical distribution at emission
(13) Top height of the vertical distribution at emission
(14) Released pollutant

Labels (15) and (16) describe the model characteristics:
(15) MOCAGE-accident grid resolution
(16) Date of the meteorological model initialisation

Labels (17) to (19) precise numerical information and position:
(17) Maximum value of the represented field
(18) A star (★) indicates the location on the map of the maximum value
(19) A triangle (▲) indicates the location on the map of the source

(20) Colour palette and value of the four concentration/deposition contours in powers of ten

(21) Date and hour of issue of the map

Figure 2 presents a description of all the information available on the 3-D trajectories map. The labelled items are as follows:

(1) Source name, Simulation type (Accident / Exercise)
(2) Release date

Labels (3) to (6) describe the source characteristics:
(3) Released pollutant
(4) Date of the beginning of the pollutant release
(5) Latitude of the source
(6) Longitude of the source

Labels (7) to (9) describe the model characteristics:
(7) Origin of the meteorological fields used in the simulation (ARPEGE / ECMWF)
(8) Model grid resolution
(9) Date of the meteorological model initialisation

(10) A triangle (▲) indicates the location on the map of the source

(11) Legend of the symbols and colours used for each trajectory and the height of the position of the particle at the initial time

(12) Date and hour of issue of the product

4.2 Complete set of MOCAGE-accident output maps for a hypothetical default scenario

In this scenario, the pollutant release begins at 19/01/2010 13:00 UTC and lasts 6 hours. The basic products are:

- 3-D trajectories starting at 500, 1500 and 3000 m above the ground,
- Time integrated surface to 500 m layer concentration for three 24-hour periods,
- Total (wet + dry) deposition during all the simulation.

The first forecast period starts at the nearest synoptic time (0000 or 1200 UTC) prior or equal to the beginning of the release time. On this example, the three forecast periods are:

- Period 1: from 19/01/2010 13:00 UTC to 20/01/2010 12:00 UTC,
- Period 2: from 20/01/2010 12:00 UTC to 21/01/2010 12:00 UTC,
- Period 3: from 21/01/2010 12:00 UTC to 22/01/2010 12:00 UTC.

Figure 3 shows the time integrated surface to 500 m layer concentration for the first 24-hour period.
Figure 4 shows the time integrated surface to 500 m layer concentration for the second 24-hour period.

Figure 5 shows the time integrated surface to 500 m layer concentration for the third 24-hour period.

Figure 6 shows the total deposition from the beginning of the release to the end of the first forecast period (20/01/2010 12:00 UTC)
Figure 7 shows the total deposition from the beginning of the release to the end of the second forecast period (21/01/2010 12:00 UTC)
Figure 8 shows the total deposition from the beginning of the release to the end of the third forecast period (22/01/2010 12:00 UTC)

Figure 9 shows the 3-D trajectories beginning at 500, 1500 and 3000 m above the ground from 19/01/2010 13:00 UTC to 22/01/2010 12:00 UTC.

5. Other products available from RSMC Toulouse

Additional products from MOCAGE-accident are provided to the forecasters. For exemple: instantaneous surface to 500 m layer concentrations and instantaneous 500 m to 3000 m layer concentrations; time integrated surface to 500 m layer concentrations and time integrated 500 m to 3000 m layer concentrations, the integration being done starting at the release time and ending at the end of the simulation; dry deposition; wet deposition...

As already stated, MOCAGE-accident can be run in “inverse” mode by RSMC Toulouse, in the context of CTBTO requests. In addition to numerical files requested, fields of view maps are plotted to the attention of the forecasters.

The air mass trajectory tool can also be run in “inverse” mode to provide the trajectory of a particle whose point of arrival (back trajectory) is specified. This spatial and temporal information gives indications about the possible origin of a detected pollution.

Note that for the short range (from 10 to 100 km, up to 24 hours only), the CMC uses the system PERLE which focuses on the local description of the atmospheric pollutant cloud. PERLE is based on a meso-scale non hydrostatic model for meteorological fields (now Meso-NH (Lafore et al., 1998) and soon AROME), coupled to a lagrangian particle model for the dispersion (LPDM from Colorado State University). Now PERLE is only used in operations over Metropolitan France.

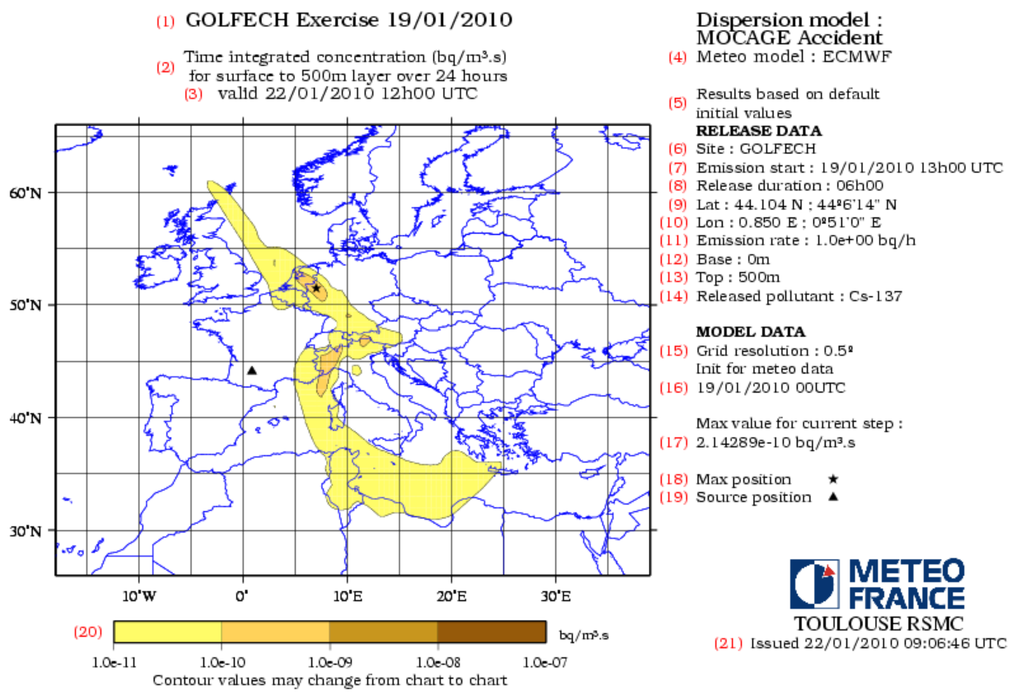

Figure 1

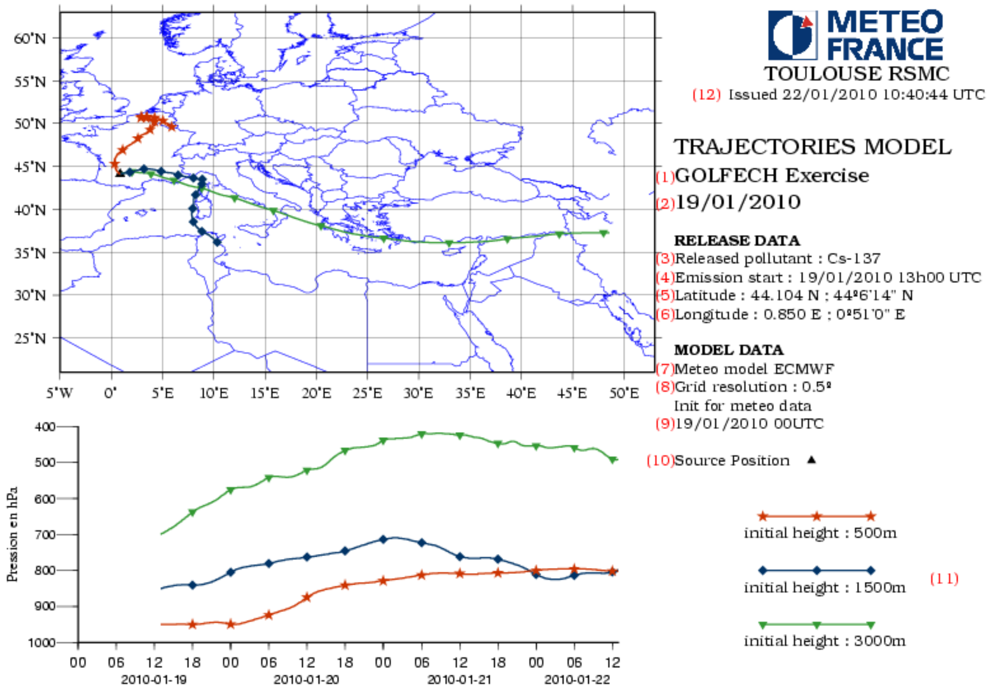

Figure 2

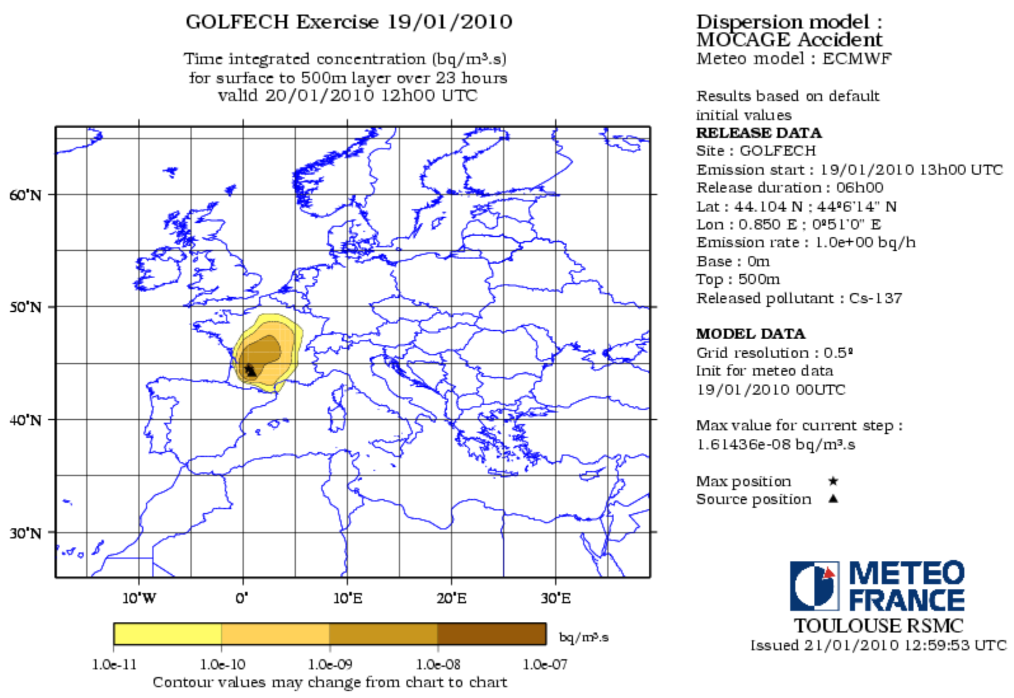

Figure 3

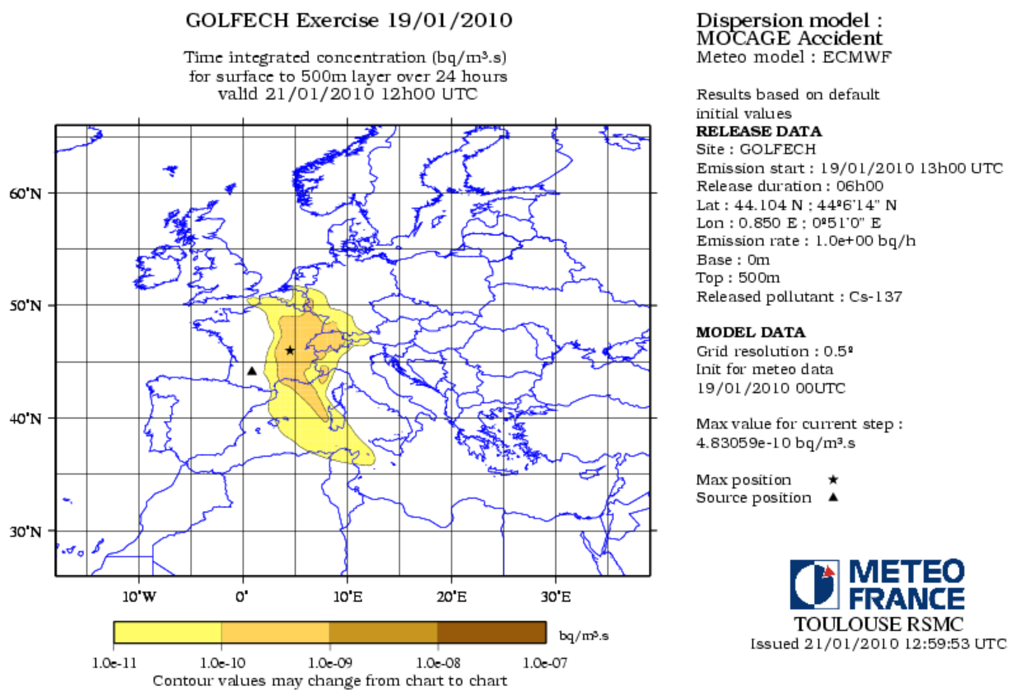

Figure 4

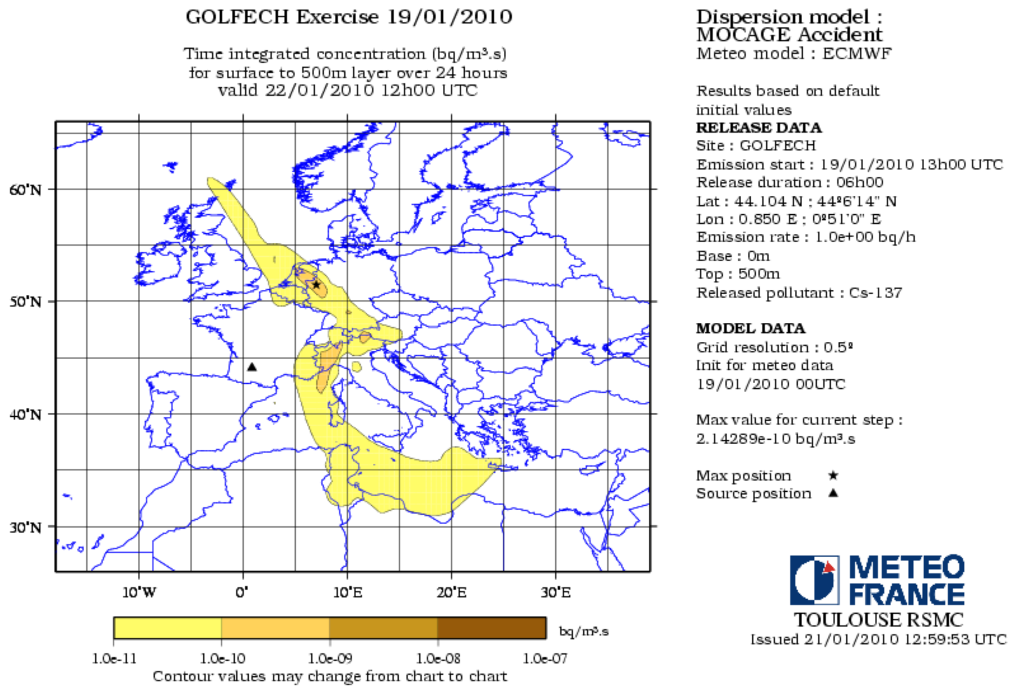

Figure 5

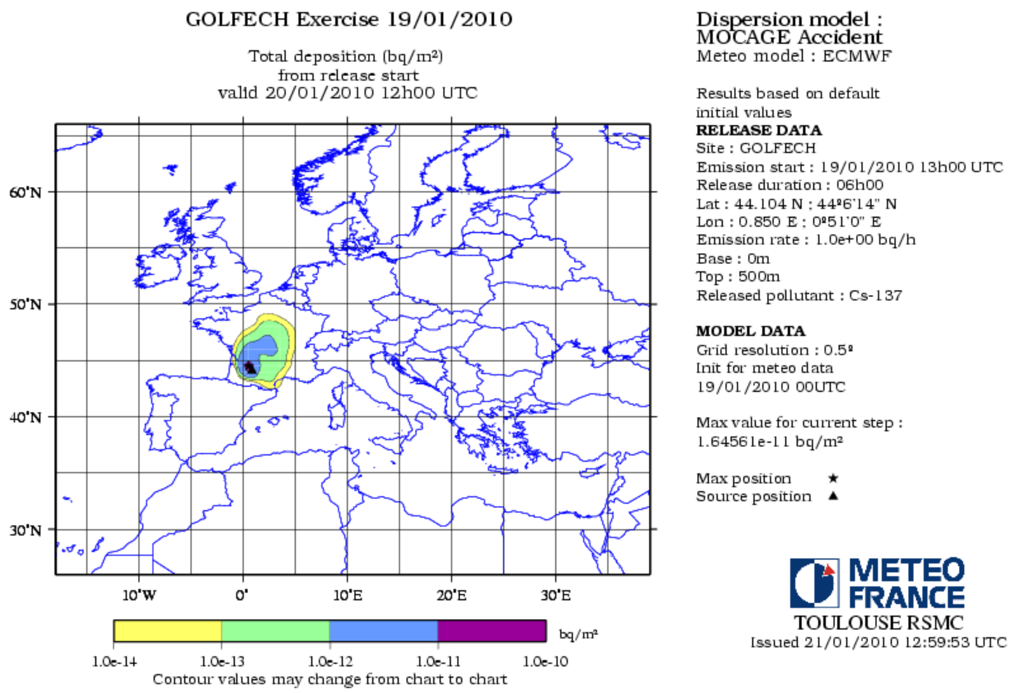

Figure 6

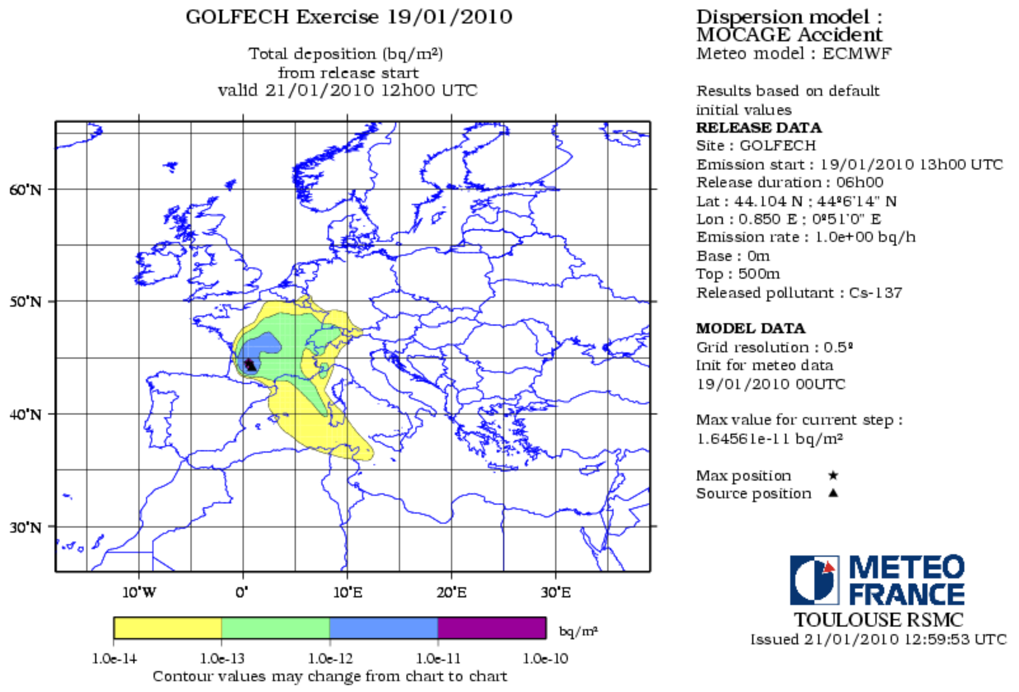

Figure 7

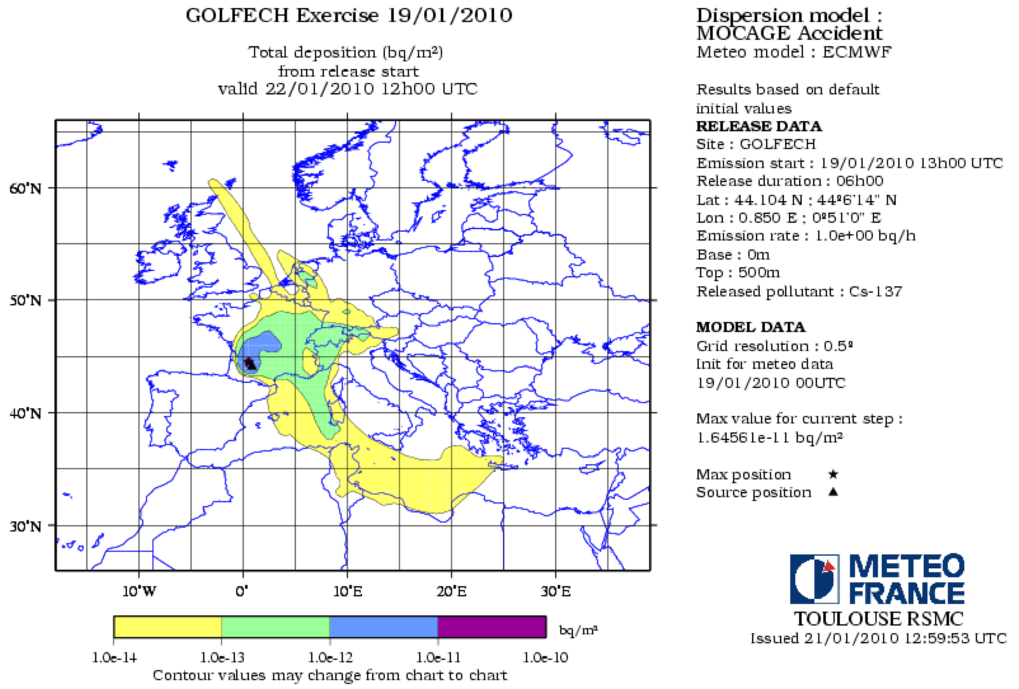

Figure 8

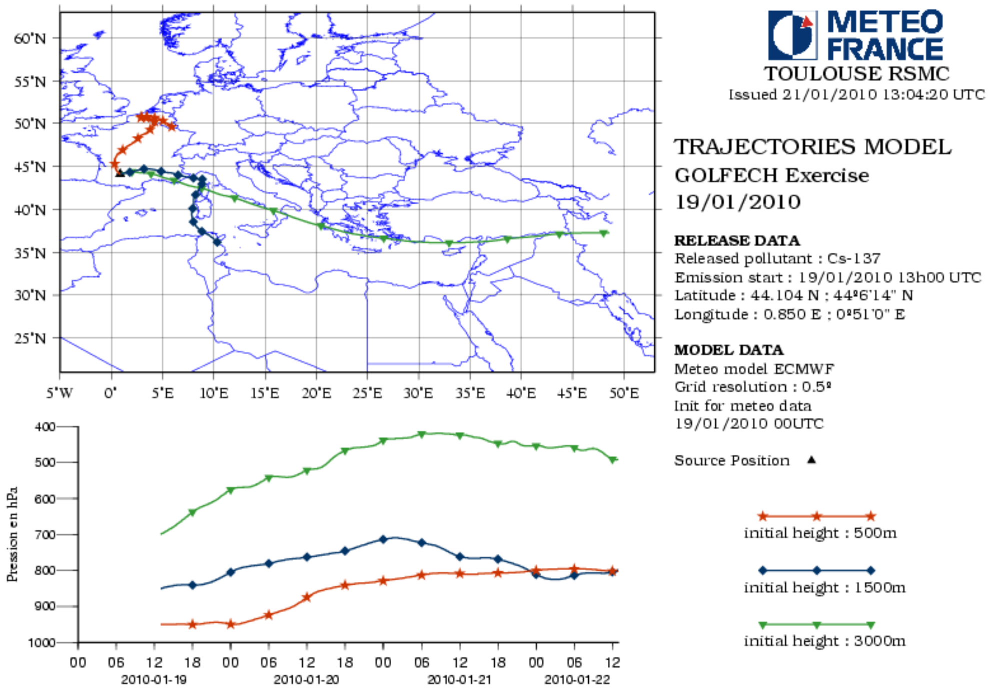
METEO FRANCE
TOULOUSE RSMC
Issued 21/01/2010 13:04:20 UTC
TRAJECTORIES MODEL
GOLFECH Exercise
19/01/2010
RELEASE DATA
Released pollutant : Cs-137
Emission start : 19/01/2010 13h00 UTC
Latitude : 44.104 N : 44º6'14" N
Longitude : 0.850 E : 0º51'0" E
MODEL DATA
Meteo model ECMWF
Grid resolution : 0.5º
Init for meteo data
19/01/2010 00UTC
Source Position
initial height : 500m
initial height : 1500m
initial height : 3000m
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E
40°E
45°E
50°E
Pression en hPa
400
500
600
700
800
900
1000
00 06 12 18 00 06 12 18 00 06 12 18 00 06 12
2010-01-19
2010-01-20
2010-01-21
2010-01-22

Figure 9