W O R L D M E T E O R O L O G I C A L   O R G A N I Z A T I O N

DOCUMENTATION ON RSMC SUPPORT

FOR

ENVIRONMENTAL EMERGENCY RESPONSE

(targeted for meteorologists at NMSs)

WMO-TD/No.778

Secretariat of the World Meteorological Organization - Geneva - Switzerland
1996 (Updated November 2011)

削除: March 2008

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CONTENTS

SECTION 1:

INTRODUCTION TO THE RSMC SPECIALIZATION FOR THE PROVISION OF ATMOSPHERIC TRANSPORT MODEL PRODUCTS FOR ENVIRONMENTAL EMERGENCY RESPONSE

1.1 The World Meteorological Organization (WMO) has designated "Regional Specialized Meteorological Centres" (RSMC) with the specialization to provide atmospheric transport model products for environmental emergency response. This capability is activated and products and services are provided within the scope and arrangements described below.

1.2 The scope of application for this specialization is the provision of modelling products and services for environmental emergencies related to nuclear facility accidents and radiological emergencies, but does not exclude other applications such as airborne plumes of volcanic ash, or other emergency situations. Furthermore, atmospheric transport modelling support is provided by the RSMC only when a large scale accident, or release of material, occurs or is likely to occur, and which has resulted or may result in an international transboundary release of significant danger affecting, or originating from, the requesting country.

1.3 The atmospheric transport models (ATM) used for the RSMC function are complex numerical models of the atmosphere which are capable of simulating long-range transport, diffusion, and deposition of airborne tracers or radioactivity in an operational response setting. Outputs from these models are made available within very short turn-around time following a request, for example within at most 3 hours following a request received by the RSMC.

1.4 The request (activation) and response arrangements, in relation to this RSMC specialization, consist of: (1) the identification of a requesting party, (2) the identification of a recipient of the Atmospheric Transport Model products, and (3) a basic set of RSMC actions which are established within the WMO in agreement with the International Atomic Energy Agency (IAEA) or agreed arrangements for support for non-nuclear environmental emergency response (see Section 2.2).

1.4.1 For the purpose of ensuring the authenticity of a request to activate the RSMC, each Member State of the WMO names one Delegated Authority contact which is the WMO recognized authority of that State to make the request. When the request made by a Delegated Authority is received by the RSMC, the RSMC immediately activates its Atmospheric Transport Model response procedures. The Delegated Authority may or may not be part of the national meteorological service of the Member State. A request for RSMC support does not relieve the requesting State of notification requirements with any relevant international organizations.

1.4.2 The RSMC's atmospheric transport model products are sent by the RSMC to the national Meteorological Service (NMS) of the WMO Member State. This is done to facilitate immediate and effective meteorological interpretation of the model output products by the requesting country's meteorological experts for their domestic use. National agencies implicated in emergency response are encouraged to make the required arrangements to ensure the effective use of RSMC products that are channelled through its NMS.

1.4.3 The WMO Member State should provide and maintain an operational contact point within its NMS to the WMO for this purpose.

References:

- Emergency Notification and Assistance Technical Operations Manual, IAEA, 1988.
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.
- Convention on Early Notification of a Nuclear Accident.
- Environment Canada and World Meteorological Organization: Proceedings, First International Workshop on Users' Requirements for the Provision of Atmospheric Transport Model Products for Environmental Emergency Response, Montréal, Québec, Canada, 1417 September 1993.
- WMO Manual on the Global Data Processing System, Appendices I.3 and II.7.

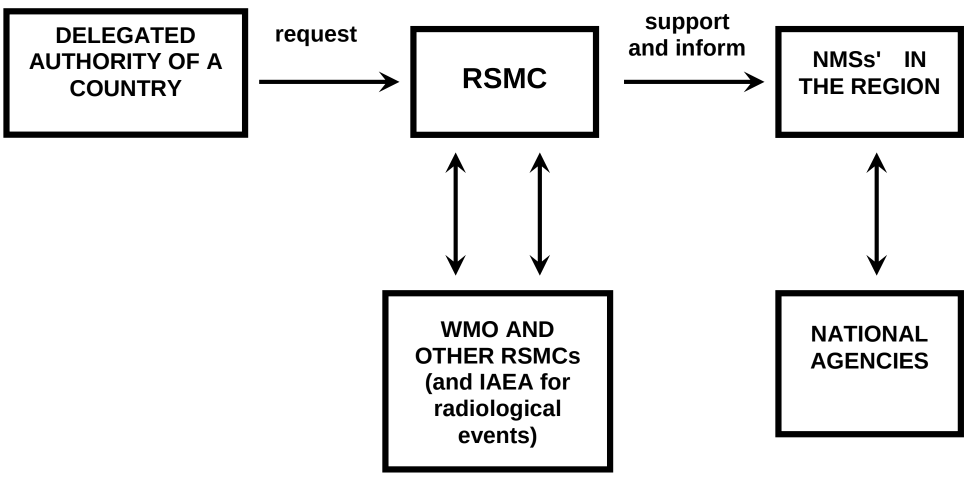

Figure 1: *Simplified diagram of the sequence of events in response to a request from the Delegated Authority of a country*

SECTION 2:

ARRANGEMENTS FOR REQUESTING AND RECEIVING ATMOSPHERIC TRANSPORT MODEL PRODUCTS FROM A REGIONAL SPECIALIZED METEOROLOGICAL CENTRE

2.1. The "Regional and Global Arrangements" are designed to ensure that the RSMCs' atmospheric transport model products would be effective for, and immediately available to any Member State, in the context of the defined Scope (parag. 1.2). These Arrangements recognize the collective role of the RSMCs, the coordinating role of the WMO, and the international authority of the IAEA for nuclear events. It is the intention of the WMO to designate RSMCs within each of its six Regional Associations so that the provision of atmospheric transport model products for environmental emergency response can be achieved within each Region under specific Regional arrangements and procedures. However, until such time as this is fully attained for all Regions, Global Arrangements are in place. The "Regional and Global Arrangements" are found in Annex 1.

2.1.1 The up-to-date list of designated RSMCs is provided with full contact information in Annex 2. A regularly updated list is given in the WMO Web Site: http://www.wmo.int/web/www/DPS/gdps-2.html#RSMCs. In Regions where RSMCs have been designated, the Delegated Authority will direct its request to that RSMC(s) according to specific Regional arrangements and procedures. A Delegated Authority in the remaining Region(s) (i.e. without RSMCs) will direct its request to the RSMC(s) specified in the Global Arrangements (Annex 1).

2.2. When the Delegated Authority or the International Atomic Energy Agency (IAEA) makes the request to the appropriate RSMC, it must provide contact information and event related information as indicated on the "Request for WMO RSMC Support by Delegated Authority" form (referred to as the "Request Form"). The language used for the Request Form is determined within specific Regional arrangements and procedures. A sample form is found in Figure 2 and a blank form is attached in Annex 3.

2.2.1 The essential contact information includes: the Status (exercise, requested services, or an emergency notified by IAEA to WMO under the Early Notification Convention (see Annex 1)), date and time of request, published name of the Delegated Authority or IAEA headquarters contact, the country or Agency it represents, its telephone and fax numbers and e-mail, the telephone and fax and e-mail of the operational contact point within the requesting country's national meteorological service where the model products will be sent.

2.2.2 The absolutely essential event-related information includes: the name of the release site, and the geographical coordinates of the release. Other event-related information, if unavailable at the time of the request, will be substituted with standard default values. At any time that new information becomes available, it should be provided to the RSMC with an updated Request Form.

2.2.2.1 The initial model runs will always use the standard defaults for the source (see Section 4)

2.2.2.2 If the information on the *time of the release* is unknown or uncertain, the “date/time of request” specified at the top of the request form will be used (see Section 4).

2.2.3 When making a request, the Delegated Authority or IAEA must send the Request Form, at a minimum completed in its first section, to the RSMC. At the same time, the Delegated Authority or IAEA headquarters contact must immediately call the

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削除: a default time (00 UTC or 12 UTC) and the date for the release

削除: , both to be established through direct consultation among RSMC(s)

RSMC to confirm the transmission of the Request for RSMC Support. This procedure must be followed in all subsequent updates of new event-related information provided by the Delegated Authority to the RSMC. Confirmation of receipt of the Request (initial and updates) will be provided by the RSMC immediately.

2.3 The RSMC(s) in response to a request for support by the Delegated Authority will produce a default set of basic products from its Atmospheric Transport Model simulation, based on actual and/or default values of input parameters. These basic products are defined and presented in section 4 and in Annex 4.

2.3.1 A text statement in conjunction with the basic products may be prepared and provided by the RSMC(s) to the national meteorological service of the requesting country. The statement would describe the Atmospheric Transport Model outputs in relation to the anticipated atmospheric circulation and weather patterns. The performance of NWP models, on which Atmospheric Transport Model simulation is based, may also be discussed.

2.3.2 Other products based on available data and related to the emergency event may be requested. The RSMC(s) will respond within its operational constraints.

2.4 After Notification of an emergency by the IAEA (by IAEA's request for basic products), the set of charts and the text statement will be sent to all NMSs of the WMO Members in the Region.

削除: <#>The Atmospheric Transport Model outputs will be updated and provided when significant new event-related information becomes available. As long as the emergency situation prevails (following IAEA confirmation), the models will be re-run with new meteorological data every 12 hours (00 UTC and 12 UTC data).

Figure 2: *Example of a Completed Delegated Authority Request Form*

ENVIRONMENTAL EMERGENCY RESPONSE ALERT
REQUEST FOR WMO RSMC SUPPORT BY DELEGATED AUTHORITY

This form should be sent by fax to the RSMC. At the same time, the Delegated Authority must immediately call the RSMC to confirm the transmission of this request for RSMC support.

(This section must be completed in full)

STATUS: NUCLEAR (EVENT) OR EXERCISE) Date/time of request: 15 JANUARY 2008 06:40 (UTC)

NAME OF DELEGATED AUTHORITY: MICHEL JEAN

COUNTRY: CANADA

DELEGATED AUTHORITY TELEPHONE/FAX NUMBERS: (......) 514-421-4622 (Tel)
(......) 514-421-4679 (Fax)

REPLY TELEPHONE/FAX NUMBERS FOR NMS OF REQUESTING COUNTRY: (......) 514-421-4635 (Tel)
(......) 514-421-4639 (Fax)

NAME OF RELEASE SITE: GENTILLY-2 (facility and place)

GEOGRAPHICAL LOCATION OF RELEASE: 46.4000N 72.3167 W (lat./long. decimal degrees N or S; E or W)

(essential accident information for model simulation — if not available, model will execute with standard default values)

RELEASE CHARACTERISTICS:

START OF RELEASE: 15 JANUARY 2008 06:15 UTC (date/time, UTC)

DURATION: .... (hours), or end of release .... (date/time, UTC)

RADIONUCLIDE SPECIES: ....

TOTAL RELEASE QUANTITY: .... (Becquerel)

OR POLLUTANT RELEASE RATE: .... (Becquerel/hour)

EFFECTIVE HEIGHT OF RELEASE: Surface: .... or
Stack height: .... (m), or
Aloft: top .... (m), base .... (m)

UNKNOWN

(helpful information for improved simulation)

SITE ELEVATION: .... (m)

LOCAL METEOROLOGICAL CONDITIONS NEAR ACCIDENT: A COLD FRONT MOVED THROUGH THE AREA AROUND 05:00 UTC. WINDS ARE NORTHWEST 15 TO 25 KNOTS. SKY IS CLEAR.
.... (wind speed and direction/weather/cloudiness, etc.)

OTHER INFORMATION: ....
.... (nature of accident, cause, fire explosion, controlled release, foreseeable development, normal activity, projected conditions, etc.)

(to be completed by RSMC)

DATE/TIME OF RECEIPT OF REQUEST: .... (UTC)

DATE/TIME OF RETURN CONFIRMATION OF RECEIPT: .... (UTC)

NOTE: All times in UTC.

SECTION 3:

AIM OF AN ATMOSPHERIC TRANSPORT MODEL (ATM) IN CONNECTION WITH NUMERICAL WEATHER PREDICTION (NWP) MODEL (SCIENTIFIC INFORMATION)

3.1 The portion of the atmosphere where the earth's surface (land or water) has a direct influence is called the Atmospheric Boundary Layer (ABL). Since most pollution releases occur in that layer, (except for aircraft emissions, volcanic eruptions or high level bomb blasts) it is important to review some fundamental concepts about the ABL structure.

3.5.1 The main feature of the Atmospheric Boundary Layer is the turbulent nature of the flow. Turbulence reinforces mixing mechanisms and tends to homogenize the properties of the atmospheric fluid much more quickly than would a laminar flow. For example turbulent mixing is an important factor in preventing local accumulation of anthropogenic pollutants.

3.5.2 The meteorological parameters are affected by the earth's surface through dynamical processes (friction of the air over the surface) and through thermal processes (heating or cooling of the air in contact with the ground).

At the top of the ABL, in the free atmosphere, the wind speed is approximately geostrophic. At the surface, the wind speed reduces to zero over land, and matches the speed of the surface currants over water. Hence a wind shear exits over the depth of the ABL which dynamically produces turbulence. The stronger is the wind aloft, the more intense is the generated turbulence. This mechanical turbulence produces a flux of momentum from the atmosphere to the surface of the earth. When there is a difference between the temperature of the surface and the temperature of the air, there is a transfer of energy between the two bodies, and a heat flux is created within the ABL. These fluxes are very different, depending on the vertical temperature gradient. Close to the surface, there exists a layer were the fluxes of heat and momentum are nearly constant with height; this layer is called the surface boundary layer (SBL) or more simply, the surface layer. In that layer, frictional effects are dominant compared to pressure and Coriolis forces. The scaling length is z_o, the roughness length, which is the height above the ground where the wind is assumed to vanish in order to take into account the rough elements of the surface. Generally three states of ABL are distinguished: neutral, unstable, and stable.

3.1.3 In the **neutral ABL**, the temperature of the surface is equal to the temperature of the air. A truly neutral ABL (potential temperature uniform throughout the whole ABL, only mechanical turbulence) is infrequent. Within the SBL the vertical wind follows a logarithmic profile. Above the SBL, the Coriolis force becomes important and the wind turns (clockwise in the Northern Hemisphere and anticlockwise in the Southern Hemisphere) with the altitude. The wind increases with height to become equal to the geostrophic wind in the free atmosphere, both in direction and velocity, at the top of the ABL.

3.1.4 In the **unstable ABL**, the temperature of the surface is greater than the temperature of the air (the surface heats the air). Buoyancy forces compound the mechanical effects and intense turbulence is generated. This layer can be divided into three zones: first, the surface layer (typically tens of meters) with a superadiabatic gradient of temperature and a rather strong wind shear, second, a mixed layer where the potential temperature and winds are almost constant with height, and third, an entrainment zone where there is a temperature inversion which caps the ABL. In the capping inversion zone, the turbulence is damped by a strong stable stratification. Some coherent structures can be frequently identified within the unstable ABL, such as convective cells or warm parcels, and can be studied as a separate subject. The unstable ABL occurs generally during the day when the solar heating is important.

3.1.5 In the **stable ABL**, the temperature of the surface is lower than the temperature of the air (the air heats the surface). The thermal effects in that case counteract the motions induced by mechanical turbulence. The surface layer shows a subadiabatic gradient of temperature over a depth of roughly ten meters. Pollutants released in that layer remain near the source. The wind is generally weak near the surface and a maximum (low level jet) is often found at the top of the temperature inversion zone. The stable ABL usually occurs during the night. In those conditions, the stable ABL is capped by an unstable layer, a remnant of the ABL produced during the previous day and in which only the dynamical turbulence remains.

3.1.6 Generally the definition of the height of the ABL is rather arbitrary. For example, the height of the ABL can be identified as the altitude where the mean vertical turbulent fluxes become "negligible". Fortunately, the ABL is often capped with a temperature inversion zone; in that case h is equal to z_i, the altitude of the bottom of this capping inversion layer. The typical height of the ABL is about 1500 meters. The diurnal variation of the ABL is illustrated in Figure 3 (Stull, 1988).

3.1.7 Many theoretical studies of the ABL have been done. The Ekman model (1902) is interesting because it provides a simple estimate of the wind variation over the whole ABL. Ekman assumed a three-way balance among the Coriolis force, the pressure gradient force and the frictional forces due to turbulent motion. It was further assumed that these frictional forces were proportional to the vertical shear of the mean horizontal wind, that the proportionality factor (the eddy diffusivity coefficient) was constant, and that the pressure gradient forces were constant in the ABL (i.e. constant geostrophic wind). With these assumptions the equations of motion lead the well known Ekman wind spiral (see appendix 1). It predicts an angle of 45° between the surface wind and the geostrophic wind. Typically, the observed angle is about 10° in unstable conditions, 15 to 20° in neutral conditions, and 30 to 50° in stable conditions. It is in the stable ABL that the Ekman model applies best.

3.1.8 A widely accepted model to describe the surface layer is provided by the Similarity Theory which states that the mean and turbulent properties in the layer depend only on the height z, and three governing parameters: a buoyancy parameter, the surface wind stress and the surface heat flux. These three governing parameters define a length scale, the Monin-Obukhov length L, a velocity scale u_*, and a temperature scale q_*. Wind and temperature profiles are given as universal functions of dimensionless combination of these scaling parameters together with the roughness parameter z_0 (see appendix 2 for more details).

3.2 With these basic principles, it is now possible to consider the modelling of the transport and diffusion of a pollutant in the atmosphere. All ATMs are governed by the "advection-diffusion equation", which is the equation of continuity for the concentration of pollutant, C.

3.5.1 The advection-diffusion equation states that the time variation of the concentration of pollutant at a point depends on several different physical processes (see appendix 3). These processes are:

a) **advection** or transport by the mean wind.

b) **diffusion** or mixing by unresolved turbulent wind eddies; in reality it is also a transport process occurring at scales which cannot be fully resolved and which must be parameterized in some fashion. The combined processes of advection and diffusion are often commonly referred to as dispersion.

c) **emission** describing the processes by which pollutants are released in the atmosphere.

d) **depletion** describing the processes by which pollutants are removed from the atmosphere. These generally take into account the effects of clouds and precipitation (wet scavenging), radioactive decay, and deposition on the ground due to the various capturing properties of the surface (dry deposition).

3.5.2 There are several types of models to simulate the Long Range Transport and Diffusion of pollutants in the atmosphere: they mainly fall in two classes: Lagrangian ATMs and the Eulerian ATMs.

Lagrangian models describe fluid elements that follow the instantaneous wind flow. They include all models in which plumes can be broken down into segments, puffs or particles. The advection is directly simulated by computing the trajectories of the plume elements as they move in the mean wind field. In models where the plume is modelled by a relatively low number of elements (puffs or plume segments) diffusion is usually simulated by a Gaussian model applied to each plume element, and the standard deviation is calculated taking into account the ABL structure. Some ATMs use a very large number of particles and diffusion is modelled by adding a "semi-random" component to the large scale wind, using Monte Carlo techniques. The probability density function for the random component, which simulates the atmospheric turbulence, is also dependent on the state of the ABL. The trajectory of each particle is calculated using these pseudovelocities, and concentrations are calculated by counting the number of particles within a certain volume.

Eulerian models directly solve the diffusion equation at every point of a grid, using numerical techniques that allow specific treatments for each physical process (finite difference method, splitting, finite element method...). The turbulent fluxes are commonly assumed to be proportional to the mean gradient according to the K gradient theory (first order closure). The horizontal and vertical K coefficients are generally dependent on the ABL structure. Precautions have to be taken in order to minimize the artificial diffusion frequently introduced by the numerical approximations.

3.3 The modelling of the source of emission, the source term description, is a crucial part of ATMs. In most cases, the processes by which pollutants are injected in the atmosphere (explosion, fire, high pressure jet, etc.) happen at scales well below those which are resolved by ATMs. The source effects have to be parameterized; the type of parameterization will depend on whether the ATM is Lagrangian or Eulerian.

(a) Information on the initial release height and its vertical extent is essential. This is illustrated in figure 4, which shows three air mass trajectories starting at the same time but at different heights. Two of them are in the ABL (500 m and 1000 m), the third one is in the free atmosphere. The results are very different, even for the "in ABL" trajectories. In this extreme case, a release in the lower layer (< 500m) would have moved south then westward along the France-Spain border towards the Atlantic Ocean. A release around 1000m would have gone straight West over the Atlantic. In the free atmosphere, however, a release would have moved eastward at the beginning, then southward over the Mediterranean Sea. Deciding on the proper countermeasures in this particular situation would not have been very easy, if no estimate of the vertical extension of the release would have been available.

(b) The time scenario is also of major importance. Of course the state of the atmosphere changes considerably with time: frontal passages, movement of pressure systems, diurnal evolution of the ABL, etc.. These will profoundly affect the evolution of the pollution cloud. For example, if a front moves over the source area, wet deposition could be a major factor for ground contamination; the deposition areas would be completely different if the release had begun before or after the arrival of the front. Furthermore, the transport/diffusion processes would also be very different and the pollutant plumes would reach different regions.

(c) If the vertical structure and the time scenario of the source term are well described, a rough estimate of the amount of pollutant is generally enough to decide on suitable countermeasures: protection of the population, food restriction, etc. In certain cases, the area of maximum air concentration and the deposition areas need only to be qualitatively known, and more accurate estimation of the plume intensity would come out of ground measurements. If accurate estimates of the amount of pollutant released are available (which seems unlikely in a emergency), the ATM could yield outputs of qualitative and quantitative interest.

(d) Information on the radiological species released is important because parameters such as dry deposition velocity, scavenging ratio, and half life are dependent on the type of pollutant; all of the depletion terms of the diffusion equation are directly related to the nature of the released elements.

3.4 Generally, ATMs used during emergencies are diagnostic or "off line" models, in order to allow for a fast and timely response. The dispersion calculations are not performed within a full scale NWP; rather, the ATMs are stand-alone models which must be provided with meteorological data from NWP models as input. So there is an impact of NWP models on the ATMs. NWP models provide data on a grid with a specific scale and all the information produced by NWP models is not necessarily available. ATMs can only simulate phenomena of the same scale as the input data mesh and sub-grid scale phenomena have to be parametrized. That is the main reason why processes such as convection or scavenging are treated in a cruder fashion in operational ATMs than in research ATMs. ATMs are of course dependent on the quality of the input meteorological data. A source of uncertainty is the precipitation field. NWP models generally only provide rain fluxes at the ground, so estimation of the depth of the wet layer must be done by ATMs. The results for wet deposition may not be very accurate, even when the precipitation areas are well estimated. ATMs will reproduce, and sometimes amplify, the NWP models errors. In the ATMES (Klug et al., 1992) experiment, evaluation of different ATMs for the Chernobyl accident, has shown that the evolution of a pollution cloud can be depicted fairly well when analysed/observed meteorological fields are used. However there is a deterioration of the models' performance when using forecast meteorological fields. That is why an evaluation of the NWP forecasts by senior meteorologists is essential. Experienced forecasters can advise the ATM specialists about the quality of the forecast meteorological fields so that the quality of the outputs of ATMs can be assessed.

3.5 ATMs generally provide two kinds of outputs: air concentration of pollutant (in unit per cubic meter) at different time steps and different levels, wet and dry deposition (in unit per square meter) at different time steps. Following the Montréal workshop on users' requirements, RSMCs are required to provide charts of time integrated pollutant concentration within the 500 meters layer above the ground, charts of total deposition (wet plus dry) cumulated since the beginning of the release to the end of the simulation, and air mass trajectories originating from three different levels.

3.5.1 Air mass trajectories represent the motion of an air parcel within the three dimensional wind field. These trajectories can reveal interesting information about the vertical structure of the atmosphere and the differences in the flow at 500m, 1500m and 3000m in the vicinity of the source of emission. It can also help explain the dispersing plume shapes. Trajectories can also provide information about differences in the predicted wind fields from different meteorological models.

3.5.2 The time integrated pollutant concentration parameter is obtained by computing the mean air concentration over the 500 first meters at each time step, and then integrating it over a predefined period. The results (in unit Becquerel per cubic meter) can then be easily related to the doses received by a human being who remains at a given point during the considered period.

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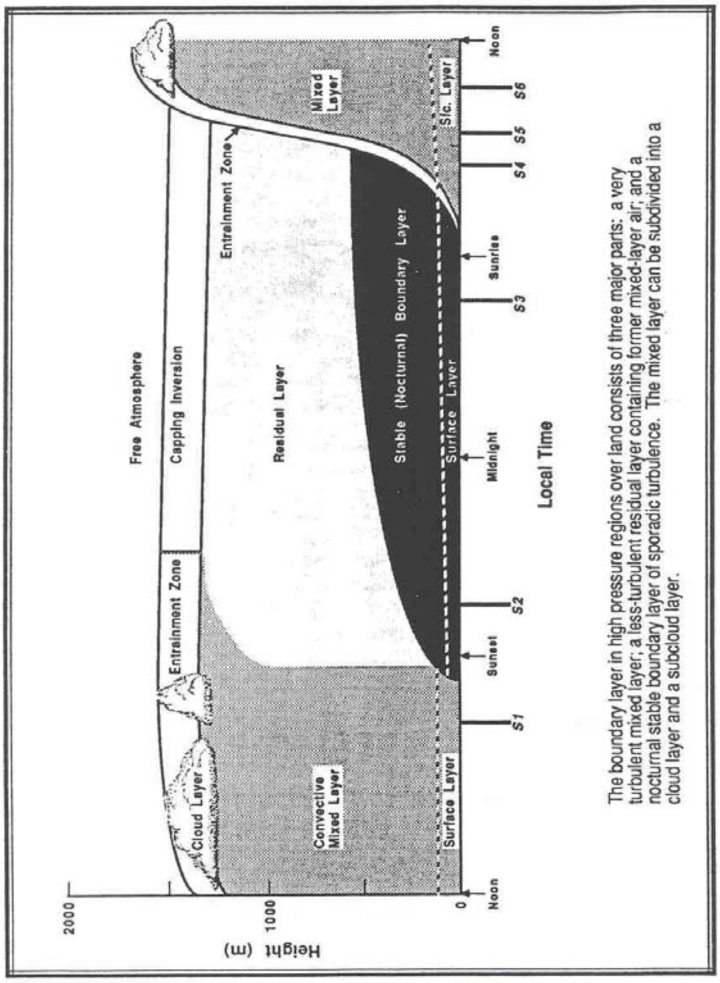
3.5.3 The total cumulated deposition parameter represents, for a radiological pollutant, the activity which is present at the ground at the end of the simulation. On this chart, dry deposition due to the uptake of pollutant by the ground and wet deposition due to the precipitations are added. This chart represents the impact at the ground of the radiological event.

References:

STULL, R.B., 1988. An Introduction to Boundary Layer Meteorology. Kluwer Academic Publishers, Boston.

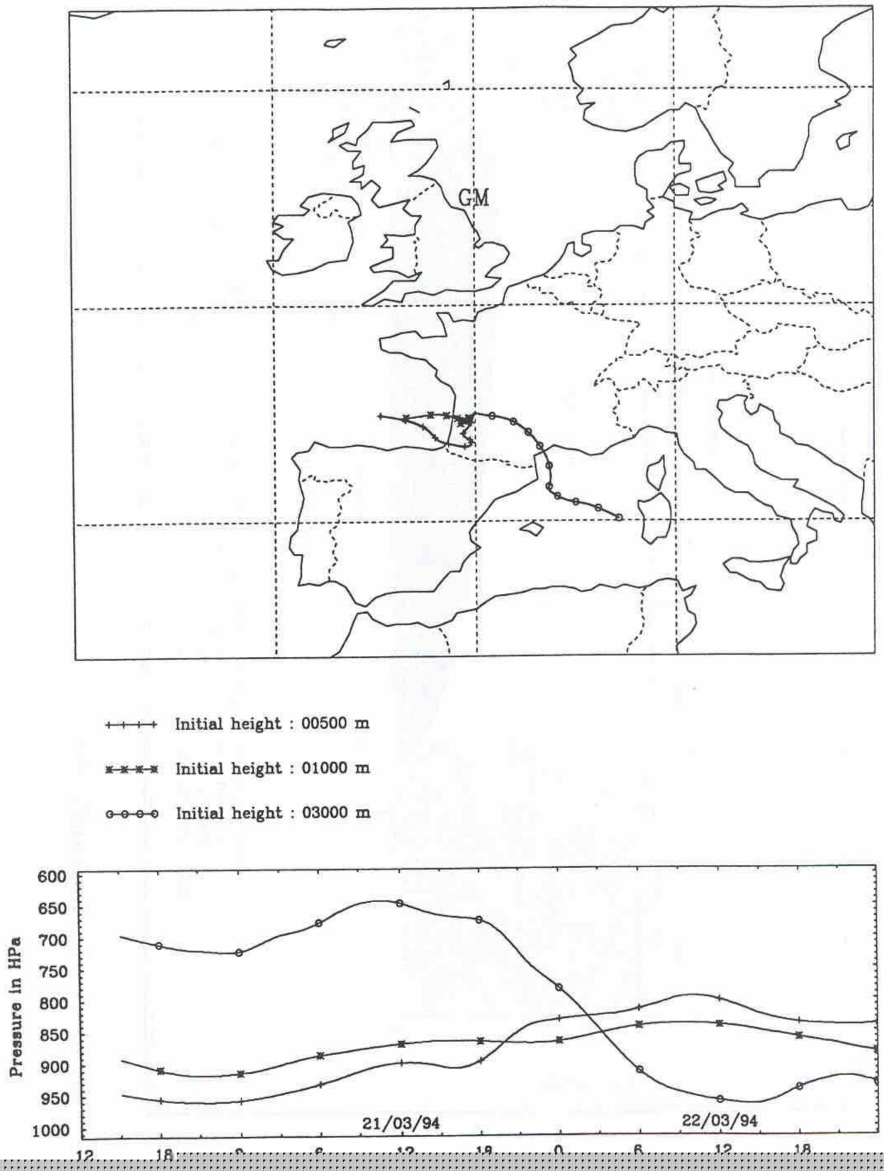
KLUG W., Graziani G., Gripa G., Pierce D and C. Tassone, 1992. Evaluation of Long Range Atmospheric Transport Models Using Environmental Radioactivity Data From The Chernobyl Accident: The ATMES Report. Elsevier Science Publishers Ltd., London and New York.



The boundary layer in high pressure regions over land consists of three major parts: a very turbulent mixed layer; a less-turbulent residual layer containing former mixed-layer air; and a nocturnal stable boundary layer of sporadic turbulence. The mixed layer can be subdivided into a cloud layer and a subcloud layer.

FIGURE 3 (Taken from Stull, 1988)

Figure 4



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APPENDIX 1: The Ekman Wind Spiral

Assuming that any variable is the sum of mean term ***A*** and a turbulent fluctuation ***A'***, (Reynold's averaging): the continuity equation for ***A*** leads to terms of the form of $\overline{u'A'}$ which represent the flux of ***A*** in the direction of the wind component u, the x direction. In the case of horizontally homogeneous turbulence in the ABL, and assuming that in the ABL, a 3-way balance exists among the Coriolis force, the pressure gradient force and turbulent momentum flux divergence, the equations of motion become:

$$f(\overline{v - v_g}) - \frac{\partial \overline{u'w'}}{\partial z} = 0$$

$$-f(\overline{u - u_g}) - \frac{\partial \overline{v'w'}}{\partial z} = 0$$

where the pressure gradient force is expressed in term of the geostrophic wind, (u_g,v_g) and v and w the y and z wind components.

Generally the turbulent flux is assumed to be proportional to the mean gradient,where K_{mz} is a diffusity coefficient. The negative sign means that the flux is from high values of A to low values.

$$\overline{w'u'} = -K_{mz}\frac{\partial \bar{u}}{\partial x}$$

$$\overline{w'v'} = -K_{mz}\frac{\partial \bar{v}}{\partial x}$$

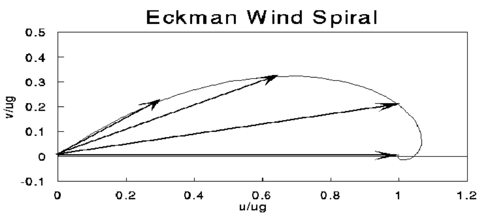
The solution of this set of equation gives for the northern hemisphere, with v_g= 0,

$$u = u_g(1 - e^{\gamma z}\cos \gamma z)$$

$$v = u_g e^{-\gamma z}\sin \gamma z$$

where $\gamma = \sqrt{\dfrac{f}{2K_{mz}}}$

The figure besides shows the wind vector at different levels, along the Eckman spiral. Levels are in terms of the dimensionless height γz (.10 π , .23π , .50π , 2.0π); the wind components are expressed in terms of $1/u_g$.



Reference:

Holton, J.R., 1992. An introduction to Dynamic Meteorology, Academic Press, Chapter 5.

APPENDIX 2: The Surface Boundary Layer and the Similarity Theory

The Similarity theory provides models for wind and temperature profiles within the surface layer. In this layer, it is assumed that, under conditions of stationary homogeneous turbulence, the vertical fluxes of momentum and heat are constant. Molecular diffusion and Coriolis effects can be neglected.

The friction velocity u_* is defined as $u_*^2 = \overline{u'w'}$

Another scaling length is the Monin Obukhov length L, defined as $L = -\frac{u_*^3}{\kappa\beta\overline{w'\theta'}}$

Where κ is the von Karman 's constant (usually equal to 0.4), θ the potential temperature

$\beta = \frac{g}{\theta_0}$ the buoyancy parameter and, $-\overline{w'\theta'}$ the vertical heat flux.

A third scaling parameter is defined : $\theta_* = -\frac{\overline{w'\theta'}}{u_*}$.

The application of these scaling parameters to the gradients of the mean profiles leads to:

$$\frac{kz}{u_*}\frac{\partial\overline{u}}{\partial z} = \phi_m(z/L)$$

$$\frac{kz}{\theta_*}\frac{\partial\overline{\theta}}{\partial z} = \phi_h(z/L)$$

Functional relationships for φ_h and φ_m are obtained from experimental data (Businger at al., 1971). These functions can be integrated to yield profiles for $\overline{u}$ or and $\overline{\theta}$.

For example in neutral conditions, the heat flux tends to zero, ***L*** tends towards infinity, depending on whether neutrality is approached from stable or unstable conditions. In that case **z**/***L*** tends to zero and φ_h, φ_m are close to unity for any value of **z**. This leads to the well known logarithmic profiles for $\overline{u}$ and $\overline{\theta}$.

APPENDIX 3: The Advection Diffusion Equation

The advection-diffusion equation is the equation of continuity for the pollutant concentration C.

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} + w\frac{\partial C}{\partial z} = -\frac{\partial}{\partial x}\overline{u'C'} - \frac{\partial}{\partial y}\overline{v'C'} - \frac{\partial}{\partial z}\overline{w'C'} + So + Si$$

This equation states that the time variation of the concentration of pollutant at a point depends on several different physical processes. These processes are:

a) advection by the mean wind $u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z}$

b) turbulent diffusion, $\frac{\partial}{\partial x}\overline{u'C'} - \frac{\partial}{\partial y}\overline{v'C'} - \frac{\partial}{\partial z}\overline{w'C'}$

c) the source term ***So***,

d) the depletion term ***Si***. It generally takes into account the effects of clouds and precipitation (wet scavenging), radioactive decay, and deposition on the ground due to the various capturing properties of the surface (dry deposition).

Wet scavenging is the result of the interaction of the pollution plume with clouds and precipitation. When entering a cloud, some of the polluted particles are absorbed by the water droplets or ice crystals and eventually reach the surface in the precipitations, this is the rainout phenomenon. Washout occurs below the cloud, when the precipitation particles scavenge some of the pollutants. Both processes are major factors for ground contamination. They are usually modelled by assuming that the local depletion rate is proportional to the concentration, introducing scavenging coefficient.

$$\frac{dSi}{dt} = \Lambda C$$

The coefficient Λ is generally assumed to be proportional to the precipitation intensity. The wet deposition rate at the ground is then the cumulation of the depletion occurring at all levels of the atmospheric column:

$$D_w = \int_0^{H_w} \Lambda C dz$$

where H_w is the height of the effective wet layer.

Dry deposition is the result of the interaction of the pollutant with the earth's surface. The polluted particles are captured by the various elements of the surface. This phenomenon is usually considered by introducing a dry deposition velocity V_d. V_d usually depends on the type of surface, the type of pollutant and the state of the SBL. The dry deposition rate at the ground is then :

$$D_d = V_d C_s$$

where C_s is the concentration of pollutant near the ground.

In case of a radioactive pollutant, another factor of depletion is the radiological decay. The equation is:

$$\frac{dC}{dt} = KC$$

where K is the radiological decay rate defined as $K = \frac{\ln 2}{T}$ (T is the half life of the isotope).

SECTION 4:

USERS INTERPRETATION GUIDE FOR ATMOSPHERIC TRANSPORT MODEL PRODUCTS PROVIDED BY RSMCs

Standards in the Provision of International Services by RSMCs for Nuclear Environmental Emergency Response

4.1 The Delegated Authority requests support from WMO Regional Specialized Meteorological Centres (RSMC) for atmospheric transport modelling products by using the form entitled “Environmental Emergency Response — Request for WMO RSMC Support by Delegated Authority”. The Delegated Authority then sends the completed form immediately to the RSMCs as per the regional and global arrangements and ensures receipt of the form by phone. This will initiate a joint response from the RSMCs in their region of responsibility.

The International Atomic Energy Agency (IAEA) requests support from WMO RSMCs for atmospheric transport modelling products by using the form agreed between WMO and IAEA. The IAEA then sends the completed form immediately, by fax and by e-mail (preferred), to the RSMCs as per the regional and global arrangements and ensures receipt of the form by phone. The lead RSMCs shall confirm receipt of the IAEA request by fax or e-mail (preferred) to IAEA. This will initiate a joint response from the RSMCs in their region of responsibility. The IAEA sends an information copy of its Request Form by fax or by e-mail (preferred) to RTH Offenbach. When the lead RSMCs’ products become available, the lead RSMCs shall send an announcement to the IAEA that their respective products are available and the products’ location (RSMC’s dedicated website), by e-mail or by fax (preferred).

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The designated RSMCs shall implement agreed standard procedures and products by:

(a) The provision of the following standard set of basic products within two to three hours of reception of a request and according to the general rules for displaying results;

(b) The adoption of the following forecast periods for the numerical calculations;

(c) The adoption of a joint response approach;

(d) The adoption of the general rules for displaying results.

Default values to be used in response to a request for products for the unspecified source parameters[1]

(a) Uniform vertical distribution up to 500 m above the ground;

(b) Uniform emission rate during six hours;

(c) Starting date/time: date/time specified at «START OF RELEASE» on request form or, if not available, then the «Date/Time of Request» specified at the top of the request form;

[1] The adoption of default values is based on the understanding that some runs of the transport/dispersion models need to be carried out with default parameters because little or no information (except location) will be available to the RSMC at an early stage. RSMCs are, however, requested to conduct and propose subsequent model runs with more realistic parameters as they become available (products based upon updated parameters will be provided on request only or confirmed from IAEA or a Delegated Authority). This may, for example, refer to a more precise assumption of the vertical distribution or the need to conduct a model run for the release of noble gases.

(d) Total pollutant release 1 Bq (Becquerel) over 6 hours;

(e) Type of radionuclide Cs 137.

Basic set of products

Seven maps consisting of:

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(a) Three-dimensional trajectories starting at 500, 1500 and 3000 m above the ground, with particle locations at 6h intervals (main synoptic hours up to the end of the dispersion model forecast);

(b) Time-integrated air borne concentrations in Bq.s m^{-3} within the layer 500 m above the ground, for each of the three forecast periods;

(c) Total deposition (wet + dry) in Bq m^{-2} from the release time to each of the three forecast times of the dispersion model forecast.

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A joint statement that will be issued as soon as available.

Forecast periods for numerical calculations

The initial set of products will cover the period from T, the start time of the release, through a forecast of 72 hours from t, the start time of the current output from the operational NWP model.

The first 24-hour period for integrated exposures in the dispersion model will start at the nearest synoptic time (0000 or 1200 UTC) prior to or equal to T. Subsequent 24-hour integrations of the dispersion model will be made up to, but not exceeding, the synoptic time nearest to t+72.

If T is earlier than t, the first response will use hindcasts to cover the period up to t.

Joint response and joint statements

A joint response means that the more than two collaborating RSMCs shall immediately inform one another of any request received; initially each should produce and send the standard set of products (charts) according to a regional agreement and then move rapidly towards providing fully coordinated response and services for the duration of the response. Following the initial response, the RSMCs shall develop and provide, and update as required, a "joint statement" to describe a synopsis of the current and forecast meteorological conditions over the area of concern, and the results from the transport models, their differences and similarities and how they apply to the event.

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4.2 General rules for displaying results

In order to make the interpretation of the maps easier, the producing centres should adopt the following guidelines:

General guidelines for all maps:

(a) Provide labelled latitude and longitude lines at 10° intervals and sufficient geographic map background (shore lines, country borders, etc.) to be able to locate precisely the trajectories and contours;

(b) Indicate the source location with a highly visible symbol (λ, σ, 6, Θ, v, etc.);

(c) Indicate the source location in decimal degrees (latitude - N or S specified, longitude - E or W specified, plotting symbol used), date/time of release (UTC), and, the meteorological model initialization date/time (UTC);

(d) Each set of maps should be uniquely identified by at least product issue date and time (UTC). And issuing centre

(e) Previously transmitted products from the dispersion model need not be re-transmitted.

(f) Indicate with a legend if this is an exercise, requested services or an IAEA notified emergency

Specific guidelines for trajectories map:

1. Distinguish each trajectory (500, 1500, 3000 m) with a symbol (σ, λ, ν, etc.) at synoptic hours (UTC);

2. Use solid lines (darker than map background lines) for each trajectory;

3. Provide a time-height (m or hPa) diagramme, preferably directly below the trajectory map, to indicate vertical movement of trajectory parcels.

Specific guidelines for concentration and deposition maps:

(a) Adopt a maximum of four concentration/deposition contours corresponding to powers of 10, but contours for less than 10^{-20} Bq.s m^{-2} of time-integrated air borne concentrations and those for less than 10^{-20} Bq.s m^{-3} of total depositions are not shown;

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(b) A legend should indicate that contours are identified as powers of 10 (i.e., -12 = 10^{-12}). If grey-shading is used between contours, the individual contours must be clearly distinguishable after facsimile transmission and a legend provided on the chart, and contour colours and shades used in the time-integrated air borne concentrations (3 chars) and the total depositions (3chars) should be consistent;

(c) Use solid dark lines (darker than map background lines) for each contour;

(d) Indicate the following input characteristics: (i) source assumption (height, duration, isotope, amount released); (ii) the units of time integrated concentration (Bq.s m^{-3}) or deposition (Bq.s m^{-2}). In addition, charts should specify: (i) "Time integrated surface to 500 m layer concentrations"; (ii) "Contour values may change from chart to chart"; and if the default source is used; (iii) "RESULTS BASED ON DEFAULT INITIAL VALUES";

(e) Indicate, if possible, the location of the maximum concentration/deposition with a symbol on the map and include a legend indicating the symbol used and maximum numerical value;

(f) Indicate the time integration starting and ending date/time (UTC).

The RSMCs will normally provide the products in the ITU-T T4 format suitable for both group 3 facsimile machines and transmission on parts of the GTS. The RSMC may also make use of other appropriate technologies.

Guidance and explanations on models and specific products issued by each RSMC

4.3 *Annex 4 presents information about the models and explanations on the specific products issued by each RSMC for the default release scenario.*

4.4 A word of caution is needed about the interpretation of the model outputs. The default scenario is based on a hypothetical source as specified in paragraph 4.1 above. For an IAEA notified emergency, the source information may remain unknown. The users should bear these in mind when analyzing the outputs. Although the models are run from high quality NWP models, inherent uncertainties must be considered as a result of the default scenario conditions and the atmospheric conditions. The interpretation of the model outputs must be done with this in mind, given the fact that the source strength and duration are usually not known. The interpretation should be done with the help of an experienced meteorologist having a strong background in synoptic meteorology and also desirably with a background in atmospheric dispersion. For an IAEA notified emergency or when better estimates of the source are available, caution is advised as to the interpretation of the outputs. This being said, model outputs offer the best available guide in a first response situation to the question of long-range atmospheric dispersion and transport of radioactive clouds. Radiological observations should be used as soon as they become available to provide collaborative information with model outputs.

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