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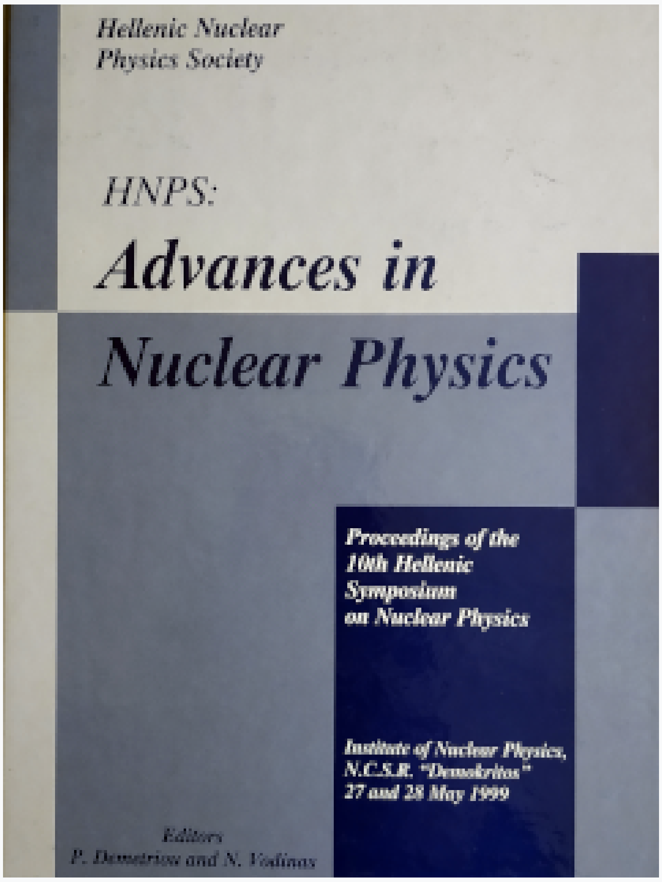

Estimating the contamination resulting from hypothetical nuclear accidents during nuclear emergency exercises

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Estimating the contamination resulting from hypothetical nuclear accidents during nuclear emergency exercises

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Abstract

An assessment of the radiological contamination of Europe, following radioactive pollutant releases and using prognostic meteorological data is presented. A modified and simplified version of SHEAR code, a Lagrangian long-range transport and dispersion model, taking into account the wind shear effect, is used. This is possible by applying the diurnal differences in vertical mixing to the winds in the vertical layer used to calculate advection. In its present version the code takes account of dry deposition processes and different mixing heights for day and night conditions. Prognostic temperature and u, v wind parameters every 6 hours for a total of 72, are provided by the National Meteorological Service of Greece in two levels 0 and 850 mb of pressure. The wind field is then calculated in both heights. This field forms an input to the SHEAR code. Plume direction and radioactive pollutant concentration have been calculated for hypothetical releases postulated during a recent NEA/OECD exercise. The results of this study indicated that the code predicted well direction and concentration of the plume, in agreement with the predictions by other programs. Since the code in this version uses surface winds, at most, which are much weaker than the higher altitude winds used by other codes, the results of the plume spread are smaller in the present study. We believe that taking into account the surface winds during an eventual accident produces more realistic results. If predictions in more heights are available mixing heights would be calculated with greater accuracy, with consequent improvement of the results.

1 Introduction

In recent years four nuclear emergency international exercises, sponsored by the Nuclear Energy Agency NEA/OECD have been developed. To affront nuclear emergency situations and calculate concentrations, doses and other important parameters two codes are used in Greece: the European PC COSYMA [1,2] and the US code MACCS [3,4]. Both codes require meteorological parameters reported to the trajectory path points. Our country participated in the exercises by using these two codes. The present work deals with the application under the same conditions of an additional code: SHEAR. The aim of this work was to develop a system to be used in emergency conditions, which does not need explicit trajectory data. This system would accept National Meteorological Service (NMS) row prognostic data and produce trajectories and concentrations. The radioactive isotopes of most importance for their radiological significance are iodine and cesium in the short and long term, respectively. The most recent European exercise has been selected for our application. The hosting country was Hungary. The exercise was held on 3-11-1998 and involved release of various radionuclides including I-131 and Cs-137. It supposed an accident in the Hungarian reactor PAKS (latitude 46° 35.5′ N, longitude 18° 51′ E). This is a Russian designed WWER pressurized water-cooled, water-moderated reactor. A large primary to secondary circuit leak has occurred in one of the steam generators of unit 4 PAKS NPP. The reactor has been automatically shut down. There has been a severe damage to the core. Radioactive material has been released to the environment through the open safety valve of the steam generator for a total amount (values at the time of exercise communication) of 4.8 x 10^{14} Bq (from which the activity of I-131 was 1.5 x 10^{13} Bq, that of Cs-137 is 3.0 x 10^{12}, the activity of Cs-134 was 2.3 x 10^{12} Bq, the activity of noble gases is 1.8 x 10^{12} Bq), creating a radioactive plume. The duration of the release was of 1 hour beginning at 7.15 UTC. The accident has been characterized as level 5 of the INES scale [5].

2 Description of the program and data used

The code used is a modified version of Shear computer code [6]. This is a Langrangian puff trajectory model which calculates trajectories and concentrations, even in long distances, of initially noble gases. The program has been tested against a lot of campaigns of gaseous releases [7,8]. With the introduction of the deposition rates of the various gases the model evaluates the transport of any radioactive gaseous release [9,10]. The code is considering variable mixing height, which is usually calculated using Heffter criteria [11,12] during the day. During the night a mixing height of 300 m is considered. In the present version we don't dispose measurements in various heights but in two heights only. So we are not able to calculate mixing height. We consider a nighttime mixing height equal to about 300 m and a daytime one equal to 1600m (in that way the upper layer wind data, at about 1500 m, of NMS can be taken into account). The wind shear effect on dispersion is obtained by splitting the daytime mixing layer in sublayers of 300 m each, at the beginning of each night. The choice of this height is mainly due to the fact that using this type of separation, the wind shear effect is well described [13,14,15]. In case a puff is released at night it remains in the lower 300 m of the atmosphere. In case it is released during the day it fills immediately the mixed layer below the temperature inversion [16]. After having so divided the vertical extent of the puff, in sublayers, each layer is considered as a separate puff with its own velocity, which could be very different in speed and direction from the rest of the layers. It is then tracked by means of a separate trajectory. During the daytime vertical mixing resumes and these elevated layers mix to the surface to affect air concentrations. Calculations are terminated when are not significant anymore.

NMS information given to us concerns temperature, rain, u and v wind speed components. From the last two, wind speed and direction is calculated. The data are given at 0 and 850 mbar of pressure in a grid of 11/2 degrees with boundaries 0° lower latitude, 82.5° upper latitude, -90° lower longitude, 90° upper longitude. They are prognostic data of hour 00 UTC of the night before the accident, and they are reported every 6 hours for 72 hours in total. So, the plume path can be calculated for three days at maximum. For this exercise we had at disposition data of the day before the exercise (02-11-98, 00 UTC), a fact that limited our wind fields a 2 days.

Trajectories are calculated at 3 hours intervals in a grid of 25 degrees latitude by 60 degrees longitude, covering thus the most of Europe. The observations closest to the trajectories are used to calculate the advection steps. The horizontal spread of the plume is due to the wind shear during the night and to the turbulent diffusion during the whole day. A σ=0.5 T (T in seconds is the time from the release) is considered [17] for daytime conditions. The concentration does not follow the gaussian curve. It is considered homogeneous in a disk of diameter 4 σ, and the air concentration in the correspondent volume is found by dividing the total mass of the puff by the area of the disk multiplied by the mixing height considered. The dry deposition depletion of the plume, by dispersion step, is considered. The dry deposition velocity for Cs-137 has been taken equal to I.0 10^{-3} m/s and for I-131 equal to 1.0 10^{-2} m/s [18].

3 Results

In case of suspected radioactive plume arrival the first actions are to evaluate its direction, the time of its arrival, the permanence in the territory of interest and the concentration of the radioactive plume in the surface layer.

For reasons of comparison with other code results we present diagrams for iodine release only. Fig. 1 presents the position of the puff and reports the maximum value of concentration 15 hours after the release at PAKS reactor. With the letter S is reported the source. Fig. 2 presents the position and the maximum of the same plume 40 hours after the release.

During the exercises, the International Atomic Energy Agency uses to distribute French (from Toulouse) and English (from Bracknell) laboratories diagrams of plume direction with estimations of time integrated concentration. Figs. 3 and 4 present the time integrated concentrations 15 and 40 hours after the hypothetical release, produced by Toulouse center, using Arpege model.

Comparing the results of the present study with French results, for the first 15 hours, we observe that the direction and the maximum concentration regions of the plume are similar. Generally the trajectories indicated a potential affect to the Northeast

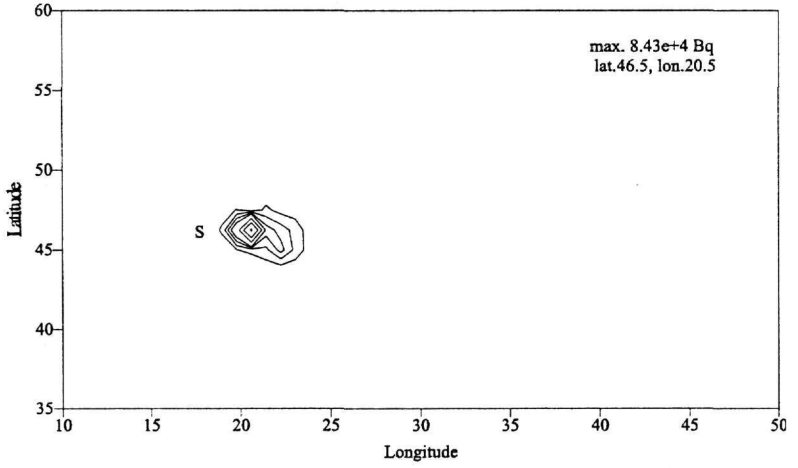

Fig. 1. Plume shape and position 15 hours after the release.

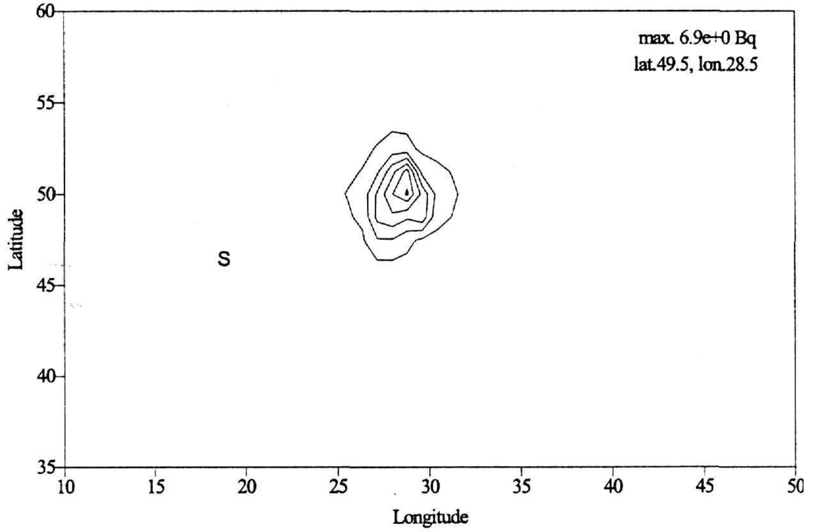

Fig. 2. Plume shape and position 40 hours after the release.

including north-east of Hungary, south-east of Slovakia, south Poland, north of Romania, Ukraine. Concerning the concentration during the first day both models predict a potentially affected area over the above mentioned countries. Both models describe an evolution of the plume towards the North East during the following days. Generally French results predict a greater extension towards east, than the results of this study. This could be explained by the fact that Arpege model uses upper air data [19] (radiosonde measurements for 24 levels) where the winds are stronger. In Figs. 3 and 4 the position of the maximum is signed with an asterisk.

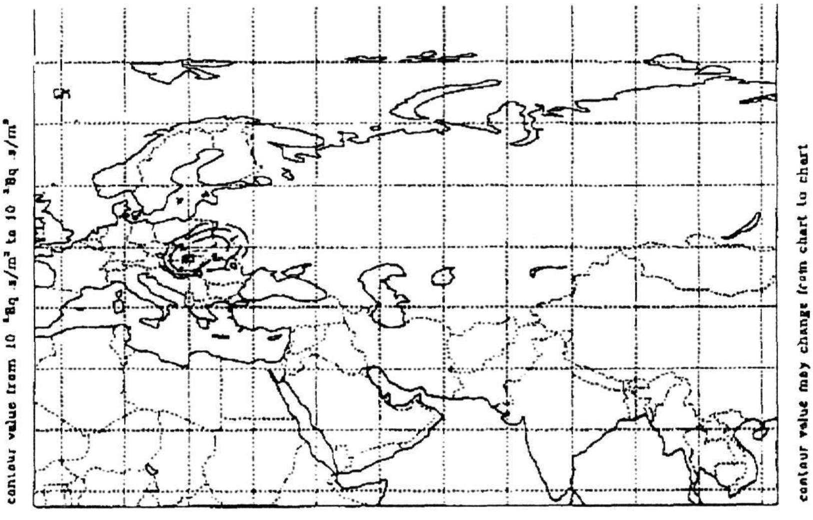

Fig. 3. Time integrated surface to 500 m layer concentration 18 h, valid on 981104 at 0 UTC.

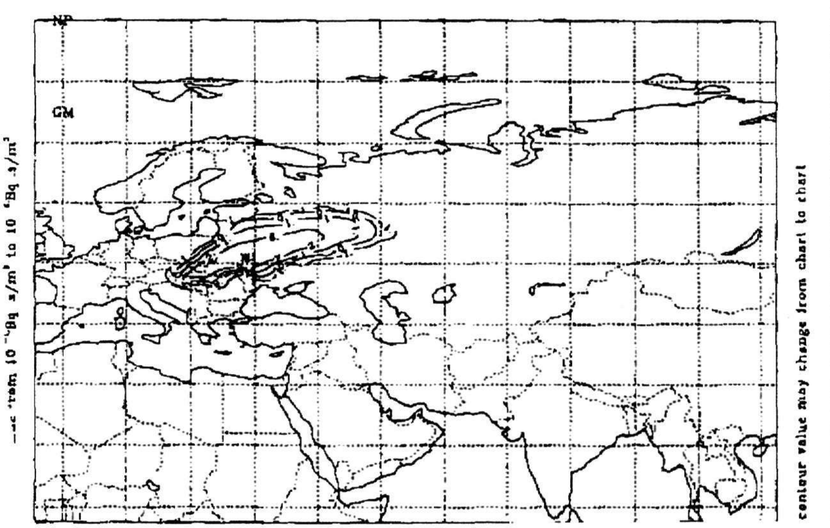

Fig. 4. Time integrated surface to 500 m layer concentration, valid on 981105 at 0 UTC.

The above prognostic results could be compared with the results of another model called HYSPLIT4 [20]. We have run HYSPLIT4 after the exercise time with real data for the days following the hypothetical release. Fig. 5 presents a 36 hours trajectory calculated by HYSPLIT4, for unitary release on 3/11/98, 7.00 UTC. Fig. 6 presents the same trajectory for a total of 120 hours. A variety of meteorological data have been used to calculate this trajectory, surface and rawinsonde measurements every 6 hours included. These data comprise parameters as wind, temperature, pressure and humidity values for at least five levels up to 850 mb level and 7 more for elevated layers. It is observed that our results, regarding the extension of the plume towards east, agree much more with the HYSPLIT4 results than with French results. This is probably due to the fact that during the considered period, the boundary layer winds were light and not very different in speed and direction from the prognostic ones used in Shear model (which were light winds for both heights considered).

4 Conclusions

In conclusion Shear code in this restricted version could be an additional useful tool to predict trajectories and concentrations, in emergency conditions when trajectory data are not known by simply using usual prognostic wind data provided by NMS of Greece when the release is known.

Acknowldgements

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References

[1] J.A Jones, P.A. Mansfield, S.M. Haywood, A.F. Nisbet, I. Haseman, C. Steinhauer, J. Ehrhartd, PC COSYMA, An Accident Consequence Assessment Package for Use on a PC. Report EUR 149169 (PREPRINT). Commission of the European Communities. Radiation Protection -62. (1993)

[2] PC COSYMA, Version 1.1, User Guide EUR, 14917EN, NRPB-SR259, Commission of the European Communities (1993).

[3] D.I. Chanin et. al., MELCOR Accident Consequence Code System (MACCS) NUREG/CR-4691, SAND86-1562, vols. 1-3 (Sandia National Labs., 1990).

[4] D.I. Chanin et. al., MACCS Version 1.5.11.1: A Maintenance Release of the Code, NUREG/CR-6059, SAND92-2146 (Sandia National Labs., 1993).

[5] INES. The International Nuclear Event Scale, International Atomic Energy Agency, and OECD Nuclear Energy Agency, April (1990).

[6] R.R. Draxler, User's guide for a long-range multilayer atmospheric transport and dispersion model. NOAA Technical Memorandum, ERL ARL-112, (1982a).

[7] R.R. Draxler, Atmospheric Environment 16 (1082) 1261.

[8] R.R. Draxler, Atmospheric Environment 16 (1982) 2763.

[9] B. M. Synodinou and G.C. Bergeles, 5th Conference on Environmental Science and Technology, Molybdos, Lesvos, September 1997.

[10] B.M. Synodinou and G.C. Bergeles, International Conference on Energy and the Environment, Limassol, Cyprus, 1997.

[11] J.L. Heffter, Air resources laboratories atmospheric transport and dispersion model (ARL-ATAD), NOAA Technical Memorandum, ERL ARL-81 (Air Resources Laboratories, Rockville. MD, 1980).

[12] J.L. Heffter, Branching Atmospheric Trajectory (BAT) Model NOAA. Technical Memorandum ERL-ARL-121. TD 9743, (1983).

[13] G.T. Csanady, Atmospheric Environment 6 (1972) 221.

[14] R.R. Draxler and A.D. Taylor, J. Applied Meteorology 21 (1982) 367.

[15] A.D. Taylor, J. Atmos. Sci. 39b (1982) 837.

[16] J. N. Carras and D. J. Williams, Atmospheric Environment 15 (1981) 2205.

[17] J. L. Heffter, J. Appl. Meteo. 4 (1965) 153.

[18] H.-J. Panitz, C. Matzerath, J. Pasler-Sauer, UFOMOD, Atmospheric Dispersion and Deposition. Institute fur Neutronenphysik und Reaktortechnik, Projekt LWR-Sicherheit, KfK 4332, Oktober (1989).

[19] http: //www.cnrm.meteo.fr:8000/dbfastex/datasel/arpege_sel.html

[20] HYSPLIT4 (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model,Web address: http://www.arl.noaa.gov/ready/hysplit4.html, NOAA Air Resources Laboratory, (Silver Spring, MD., 1997).

Fig. 5. Trajectory of unitary mass released at PAKS site on 3-11-99 07 UTC, for the following 36 hours.

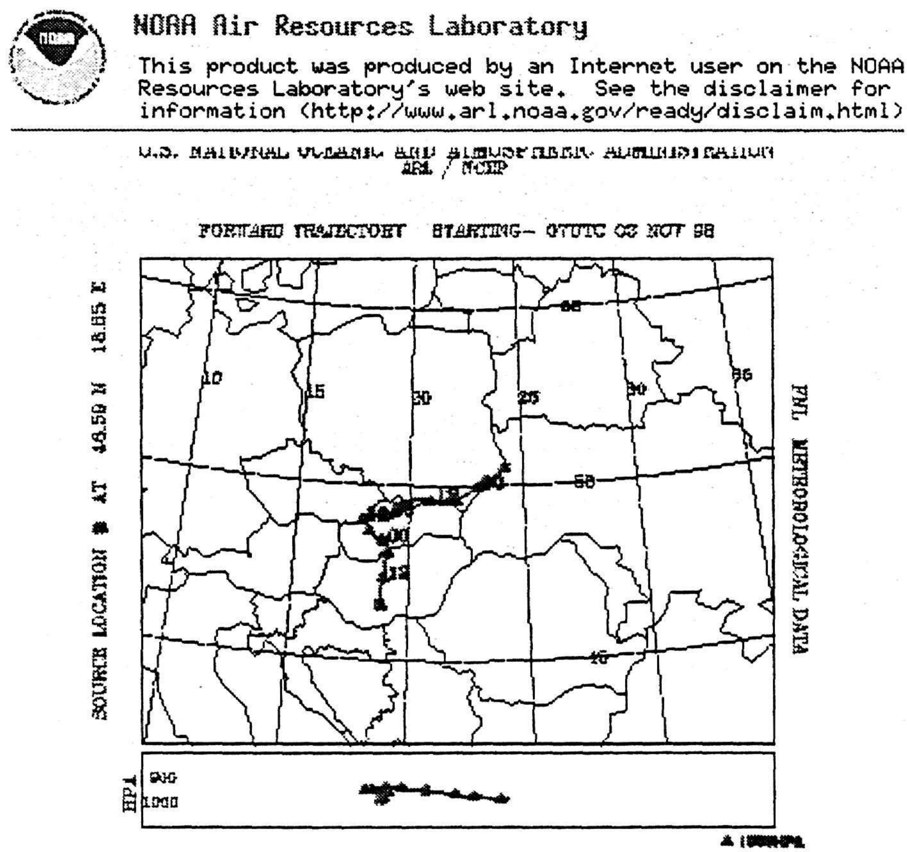

Fig. 6. Trajectory of unitary mass released at PAKS site on 3-11-99 07 UTC, for the following 120 hours.