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Extended Abstract

Evaluation of a Long Range Particle-In-Cell Transport and Diffusion Model Based on an Analysis of the Chernobyl Reactor Accident

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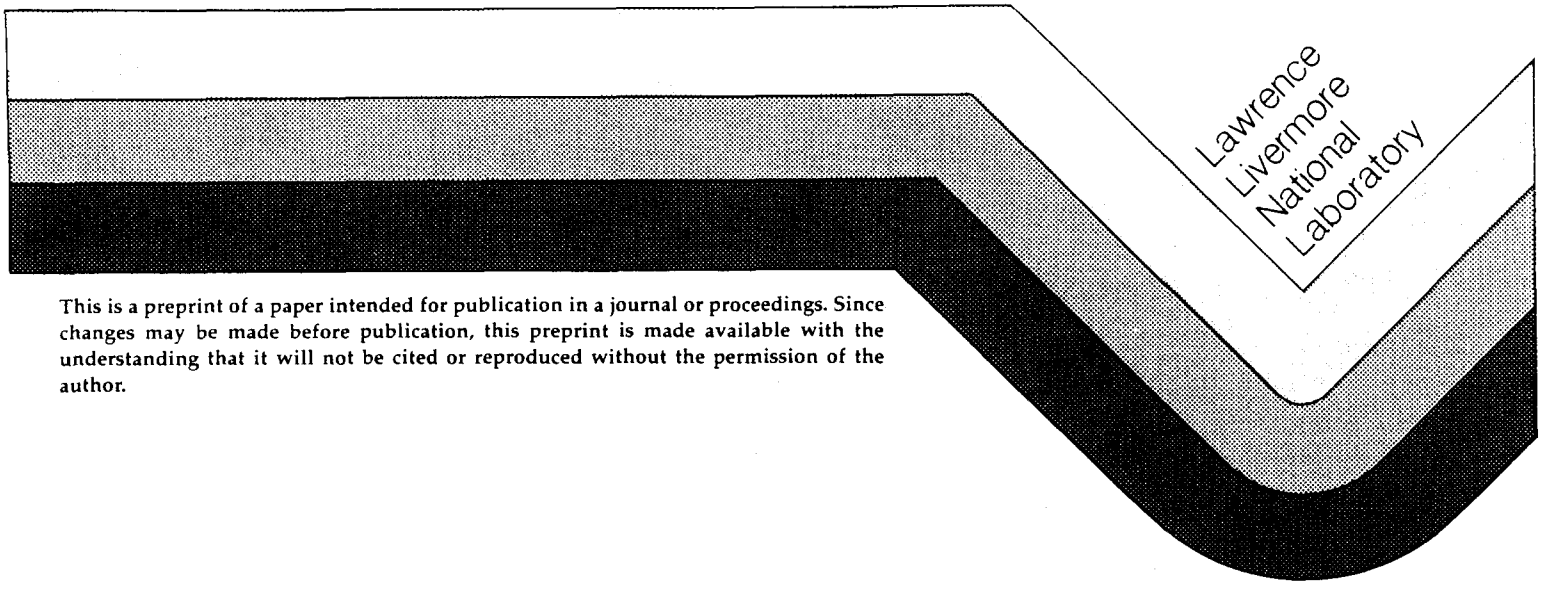

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Summary of Past Work

Work described in this presentation was accomplished over an eighteen month period after the Chernobyl accident, during which time model calculations were compared to environmental measurements supplied by the WHO as well as several individual countries. Results of these calculations and comparisons to measurements have been published in several reports with the most complete description of these studies provided by Lange, 1988. Using the source term data shown in Table 1, the spatial distribution of material released from the Chernobyl reactor is shown by Figure 1. After four days (Figure 1.b) material is moving in three major directions: (1) the lowest layer, within the first 1500m, is dispersed over Eastern Europe and Scandinavia, (2) another large collection of particles located above about 4 km are moving toward the Middle East, and (3) the third group of particles are moving east toward Japan. By day 10 (Figure 1.d) material has reached the western United States and is spreading over most of the Northern Hemisphere with the exception of eastern North America.

Figure 2 shows the 24 hour averaged ^{131}I surface air concentrations (Bq/m^3) over Europe for four daily time periods out to May 3, 1986. It should be noted that rainout was not included in these calculations. Also, due to the coarse resolution of the mesh used for these calculations, local concentration estimates can be up to two orders of magnitude low as pointed out by Lange, 1988. Table 2 lists a comparison between measured and calculated surface air concentrations (Bq/m^3) and cloud arrival times. Comparisons for ^{131}I appear to be very reasonable, i.e., approximately 60% are within a factor of two while comparisons for ^{137}Cs did not reach this level of accuracy. It is not clear at this time why the difference is this large between the two radionuclides. Arrival times agree well

with many of the observations, leaving Austria, Hungary, France, Southern Italy, United Kingdom, and Kuwait as the exceptions. Again it is difficult to determine why these differences occur; however, some possibilities are discussed below.

Model Improvement

Below are listed the model improvements we have made since the work discussed in this presentation was completed and other improvements we hope to complete in the future. As part of this process we plan to use the ANATEX data set that is described by another participant in this meeting.

1. Implemented

a. The PATRIC model (Lange, 1978a) was merged with ADPIC (Lange, 1978b) to generate HADPIC providing a tool for evaluation of transport and diffusion of pollutants from the local to the hemispheric scale. The HADPIC model is interfaced directly to hemispheric forecast and analysis wind field data bases provided by the U.S. Air Force Global Weather Central.

b. Based on Chernobyl modeling results preliminary adjustments were made to the diffusion parameters in ADPIC to simulate dispersion on the hemispheric scale.

2. Future

a. Monte Carlo Diffusion. Particle-in-cell models like ADPIC or HADPIC lend themselves well to a random walk type of diffusion calculation. This method has the advantage that it needs no computational grid for the diffusion calculation, and hence is free from grid resolution problems. It is proposed to implement this method into HADPIC and compare the results with the gradient diffusion theory now used in the code. It will be particularly useful when HADPIC is used on scales from the mesoscale on upward to hemispheric scales, where grid cells become very large, and the code might essentially always run in the source particle (Gaussian)

mode because plume concentration gradients are not resolved. This method will replace, or compliment, the gradient diffusion module and will replace the limited Gaussian source particle prescription in the present HADPIC.

b. Mesoscale Hydrodynamic Model. The development of a mesoscale forecasting model to be used as an alternative wind field driver to MATHEW to compute pollutant dispersal with HADPIC requires several adaptions of HADPIC. These include, transformation to terrain following coordinates if a finite difference forecast model is adopted, or some interpolative process of the wind field or both. Monte Carlo type diffusion appears preferable in either case. This development should include variable vertical cell spacing to improve resolution near the surface.

c. Diffusion Parameterization. K profiles for a double boundary layer separated by an inversion are needed for HADPIC, as well as K profiles for the troposphere above the boundary layer. This would include space and time varying energy dissipation rates on a hemispherical scale.

d. Surface Types. Lower boundary surface types (e.g., sea versus land surfaces) need to be included in HADPIC, particularly as they relate to the vertical diffusion parameterization.

e. Wet Precipitation. Implementation of the wet deposition formulation in HADPIC needs to be addressed with an eye on being able to merge time and space dependent precipitation deposition from both measurements and forecast models.

f. Topography. Topography needs to be introduced into HADPIC.

Acknowledgements

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References

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Lange, R., 1978b, ADPIC—A Three-Dimensional Particle-In-Cell Model for the Dispersal of Atmospheric Pollutants and its Comparison to Regional Tracer Studies, *J. Appl. Meteor., 17,* 320–329.

Lange, R., 1988, Dose Estimates from the Chernobyl Accident, *Nuclear Technology,* Vol. 82, No. 3.

Appendix A: Tables and Figures

Table 1. Activity fraction relative to ^{137}Cs and estimated activity released, decay corrected to 26 April 1986 (Lange, 1988).

Nuclide	Fraction	Activity Released (Bq)
^{137}Cs	1.0	8.9×10^{16}
^{136}Cs	0.2	2.0×10^{16}
^{134}Cs	0.5	4.8×10^{16}
^{131}I	20.	1.7×10^{18}
^{133}I	42.	3.7×10^{18}
^{141}Ce	0.1	8.9×10^{15}
^{144}Ce	0.06	5.2×10^{15}
^{140}Ba	0.5	4.4×10^{16}
^{140}La	0.5	4.4×10^{16}
^{95}Zr	0.1	8.9×10^{15}
^{95}Nb	0.1	8.9×10^{15}
^{132}Te	4.2	3.7×10^{17}
^{103}Ru	0.3	3.0×10^{16}
^{106}Ru	0.06	5.2×10^{15}
^{133}Xe	—	6.5×10^{18}

Table 2. A comparison between measured and calculated surface air concentrations (Bq/m^3) and cloud arrival times. (Lange, 1988)

Location	Dates	^{131}I Concentrations		^{137}Cs Concentrations		Cloud Arrival Time	
		Meas.	Calc.	Meas.	Calc.	Calc.	Meas.
Nurmijarvi (Finland)	4/29–5/3	3.7	3.8	0.08	0.6	4/27	4/27
Stockholm	4/28–5/6	3.6	8.0	0.2	1.1	4/27	4/27
Kjeller (Norway)	4/28–5/5	6.2	9.5	0.2	1.3	4/27	4/27
Munich	4/30–5/6	7.0	6.5	1.7	0.9	4/30	4/30
Austria	4/29–5/5	3.5	4.2	–	–	4/30	4/29
Budapest	5/1–5/5	3.0	4.2	0.6	0.5	4/30	4/29
N. Italy	4/30–5/6	17	6.6	0.7	0.4	4/30	4/30
S.E. France	5/1–5/6	9.8	6.6	0.4	0.7	4/30	4/29
Paris	5/1–5/7	0.7	3.7	0.2	0.5	5/1	4/29
S. Italy	5/1–5/6	8.0	1.9	0.6	0.2	5/2	5/1
Netherlands	5/1–5/5	7.1	9.3	–	–	5/2	5/2
Berkeley (U.K.)	5/1–5/3	0.3	0.5	0.05	0.02	5/3	5/2
Chilton (U.K.)	5/2–5/3	5.4	4.5	0.9	0.2	5/3	5/2
Athens	5/3–5/5	29	18	–	–	5/3	5/3
Kuwait	5/4–5/9	0.3	0.1	0.06	0.03	5/7	5/5

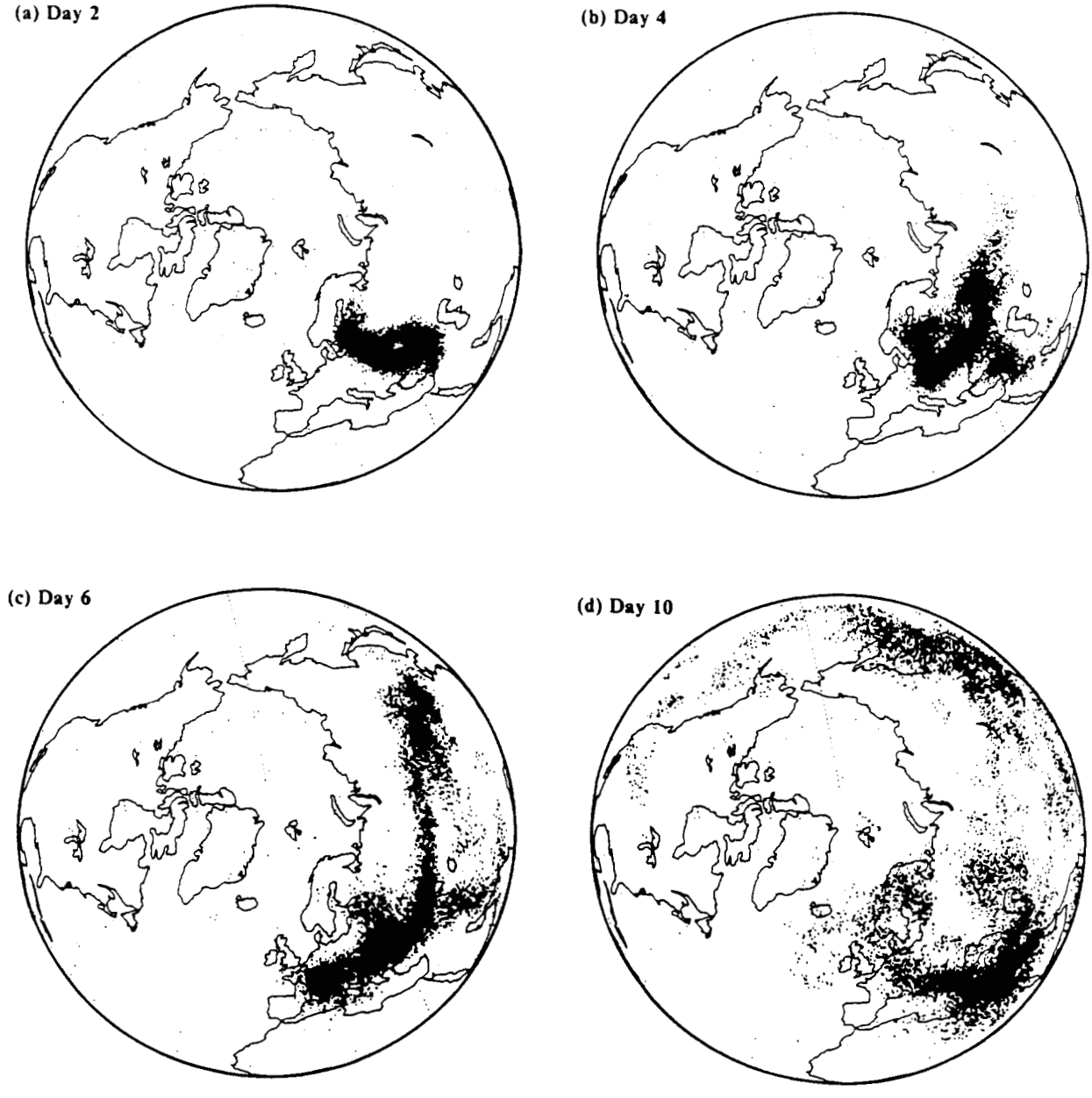

Figure 1. ARAC plots showing how the clouds of radioactive material spread around the Northern Hemisphere at (a)2, (b)4, (c)6, and (d)10 days after the initial explosion (Lange, 1988).

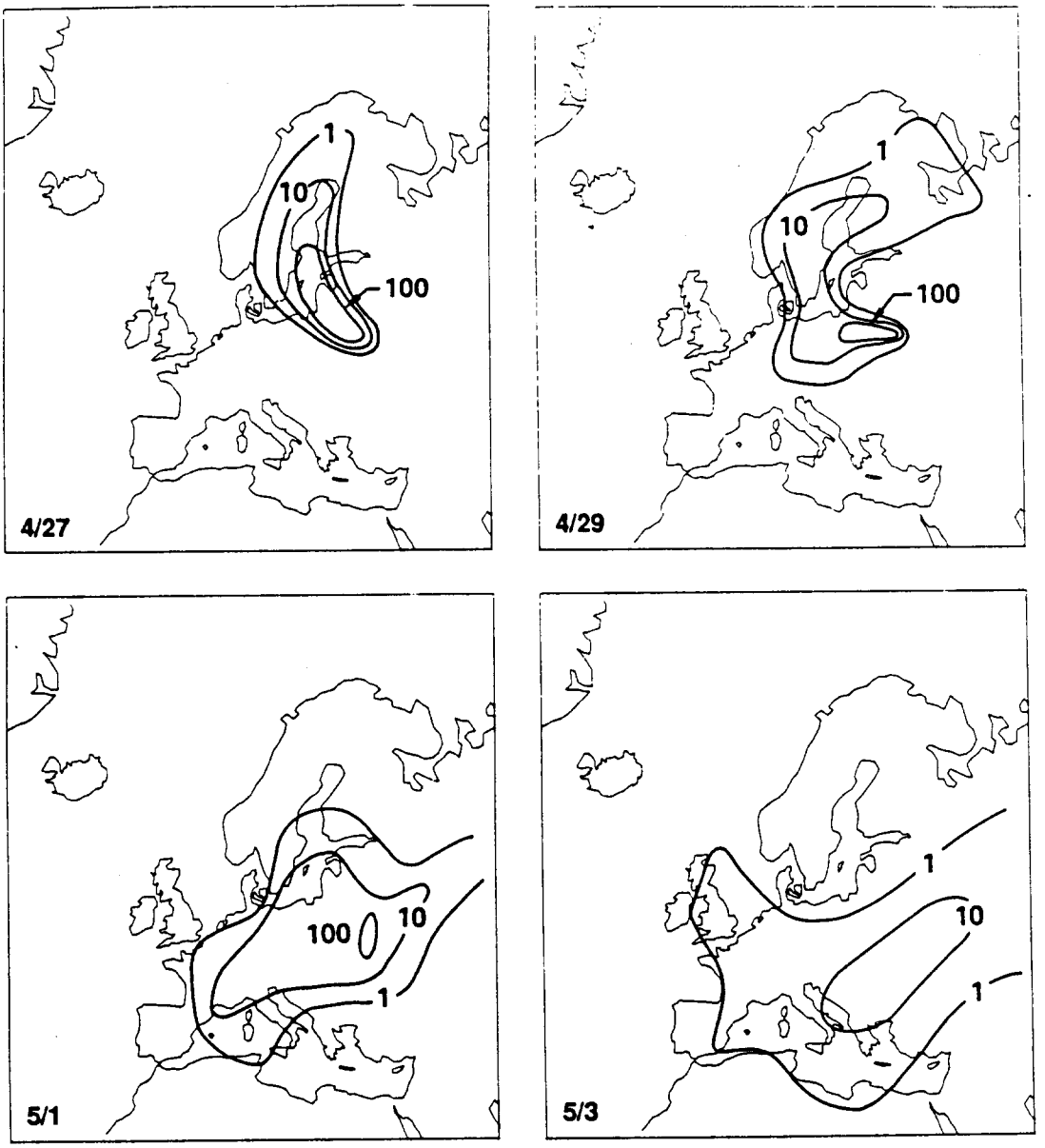

Figure 2. ^{131}I 24 hour averaged surface air concentration patterns over Europe (Bq/m^3) based on the PATRIC model for dates listed (Lange, 1988).

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