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SIMULATION OF ATMOSPHERIC DISPERSION OF RADIOACTIVITY FROM THE CHERNOBYL ACCIDENT*

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Measurements of airborne radioactivity over Europe, Japan, and the United States indicated that the release from the Chernobyl reactor accident in the Soviet Union on April 26, 1986 contained a wide spectrum of fission products up to heights of 7 km or more within a few days after the initial explosion. This high-altitude presence of radioactivity would in part be attributable to atmospheric dynamics factors other than the thermal energy released in the initial explosion. Indications were that two types of releases had taken place—an initial powerful explosion followed by days of a less energetic reactor fire.

The Atmospheric Release Advisory Capability[1] (ARAC) at the Lawrence Livermore National Laboratory (LLNL) utilized three-dimensional atmospheric dispersion models to determine the characteristics of the source term (release) and the evolution of the spatial distributions of the airborne radioactivity as it was transported over Europe and subsequently over the northern hemisphere. This paper describes the ARAC involvement and the results of the hemispheric model calculations which graphically depict the extensive dispersal of radioactivity.

The Chernobyl source term estimations and the European and hemispherical inhalation dose estimates were computed with a three-dimensional sequential puff transport and diffusion model which was adapted to the hemispheric troposphere from its original purpose to assess the global transport of the stratospheric radioactivity cloud generated by Chinese atmospheric nuclear weapons tests. The model used is a simplified version of the ADPIC model[2], and is based on the particle-in-cell concept. This technique involves the generation of a large number of marker particles to represent the radioactivity distribution. These particles are injected as a sequence of puffs at the source point, and are subsequently transported within a three-dimensional Eulerian grid mesh by means of a transport velocity applied to each particle. This transport velocity consists of a wind velocity provided at each grid point and a diffusion velocity based on Gaussian diffusion (gradient diffusion in ADPIC). In addition, gravitational settling and dry deposition velocity as well as radioactive decay is applied to the particles, as appropriate. For Chernobyl, effects of terrain and wet deposition due to precipitation scavenging, were not included. Summing the resulting distribution of particles over the grid mesh volumes allows determination of the three-dimensional concentration distributions that are needed for dose estimations.

The results obtained with the source inventories of 1.7 x 10^{18}Bq for ^{131}I and of 8.9 x 10^{16}Bq for ^{137}Cs, contain a detailed analysis of the time-varying horizontal and vertical spatial distributions of airborne radioactivity. These indicated that the cloud became

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segmented during the first day, with the lower section heading toward Scandinavia and the upper part heading in a southeasterly direction, with subsequent transport across Asia to Japan, the North Pacific, and the United States. To demonstrate the evolution of the activity distribution as modeled by the marker particles Fig. 1 shows the calculated particle pattern over the northern hemisphere at days 2, 4, 6, and 10 after the initial release.

By the end of April 27 (day 2) the activity near the surface had traveled in a northwesterly direction, toward Scandinavia, passing over the northeastern corner of Poland. The activity distribution continued its expansion into Scandinavia by April 29, at the same time moving toward eastern and central Europe. The emissions during this period were also transported eastward. By May 1, the surface activity had spread throughout central and southern Europe as well as east and south of the Chernobyl area. By May 5, nearly the entire northern hemisphere was engulfed, with material having reached the United States.

This widespread activity distribution predicted by the model is in agreement with observations of large tropospheric pollution clouds[3,4]. The quasi two-dimensional, large-scale tropospheric eddies form an efficient tool to cause distortion and deformation of such clouds and contribute to their spreading. In the case of the Chernobyl plume, a low pressure system near the source drastically increased its size.

Operationally, today ARAC has its models adapted such that it can serve any scale within a few hours or less. At the hemispheric scale, we now have an operational version of the ADPIC model and routinely receive gridded wind data from the Air Force Global Weather Central (AFGWC) for the northern hemisphere. A preliminary test of our model demonstrated that we have a fledgling capability in the southern hemisphere. Since we do not routinely receive the data for this region of the world, any response calculations in this hemisphere would require several hours to acquire the data sets.

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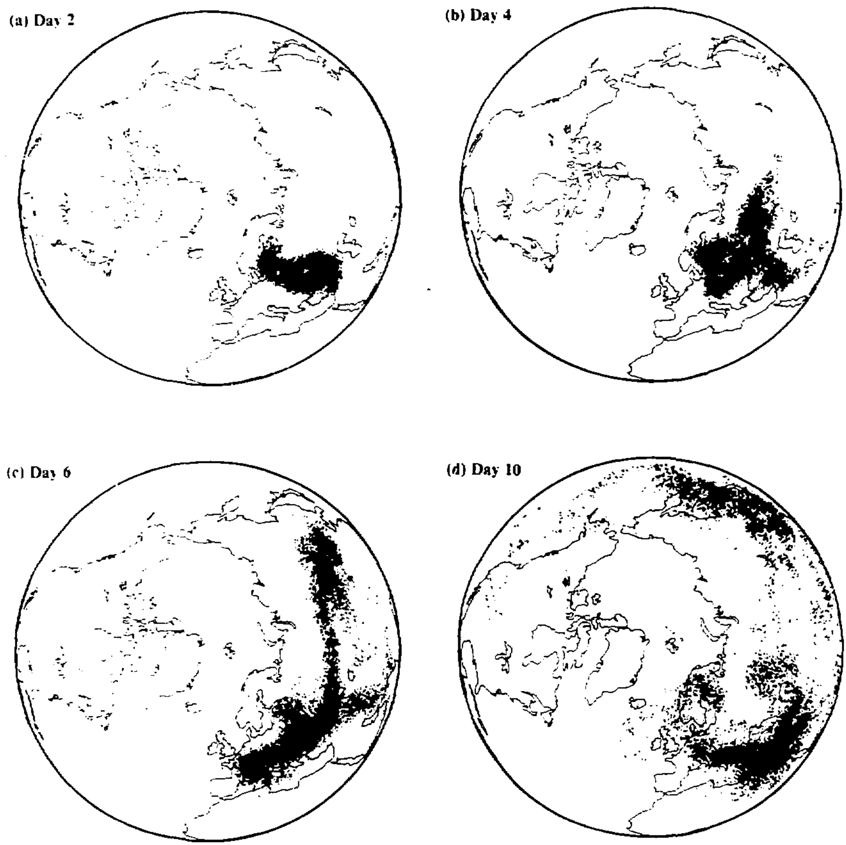

Fig. 1. ARAC plots showing how the clouds of radioactive material spread around the northern hemisphere at (a) 2, (b) 4, (c) 6, and (d) 10 days after the initial explosion.

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