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SELF-INDUCED RAINOUT FROM A NUCLEAR WEAPON

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1. INTRODUCTION

The possible employment of nuclear weapons in a tactical nuclear war has led to consideration of potential collateral damage on friendly troops and civilians. For the past six years we have been involved in a rainout research program to assess the potential collateral damage due to rainout. We have concluded in previous research that a militarily significant collateral damage hazard would occur approximately 10% of the time in Western Europe due to scavenging of radioactive debris by natural precipitation (Knox and Molenkamp, 1977).

Several years ago we conjectured that detonation of a nuclear weapon could initiate the formation of a convective cloud that would precipitate and rapidly scavenge and deposit a large amount of radioactive debris. We call such an event self-induced rainout.

2. NUMERICAL SIMULATION

To investigate the possibility and consequences of self-induced rainout, we used a convective cloud scavenging model that we had developed to simulate scavenging and deposition of submicron radioactive debris particles by naturally occurring convective clouds. The cloud dynamics and microphysics of this model are basically the axisymmetric version of the RAND Cumulus Dynamics Model (Murray and Koenig, 1972) to which we have added a scavenging parameterization. To simulate self-induced rainout, we assumed that the buoyancy perturbation resulted from local heating due to detonation of a nuclear weapon and that the radioactive debris was initially suspended within the locally heated region.

Our simulation of a 1 kt free air-burst of a nuclear weapon, using a sounding from Germany on a day when there were scattered convective showers, predicted that self-induced rainout would occur. Precipitation commenced about 15 min after detonation and continued for about 20 min before the cloud dissipated. Radiation dose rate contours one hour after the detonation, assuming the cloud moved downwind at 5 m sec^{-1}, are given in Fig. 1. This model simulation supported our conjecture that self-induced rainout could occur and would deposit militarily significant amounts of radioactive debris on the ground several kilometers downwind of the burst point.

3. OBSERVATIONS

Because of the results of our model simulation of self-induced rainout, we took a cursory look at nuclear test data to see if we could find any observational evidence of self-induced rainout, but we found none. This is not too surprising since tests in Nevada were always timed to avoid precipitation, which is easy to do in such an arid climate. In the Pacific tests the observers were not stationed in positions where they would have been likely to observe self-induced rainout, especially if they were not expecting it.

About two years after completing the model simulation of self-induced rainout, we acquired a report summarizing the doses received by the survivors of the bombings of Hiroshima and Nagasaki, which mentions the "black rain" phenomenon (Auxier, 1977). Subsequent investigation has shown that rainout of fresh weapons debris occurred at both Hiroshima and Nagasaki. It was not raining at the time of the burst; in fact, one criterion for release of the bomb was visual sighting of the target. Rain commenced 20-60 min after the burst, which is just about the time convective cloud models predict for a cloud to develop to the precipitation stage. Rain fell only at locations downwind of the burst point, and rain amounts were large (in fact, there was local flooding reported in Hiroshima). Rain continued through most of the day, and large amounts of soil and soot were deposited with the rain, hence the name "black rain." Intense fires raged in both cities all day and into the night; these fires possibly forced development of convective precipitation throughout the day.

Dose patterns of deposited radioactivity as measured by the U. S. team about 60 days after detonation are shown in Figs. 2 and 3 (Arakawa, 1959). The contours at the center of the burst are due to neutron-induced radioactivity and gamma rays. The rainout-deposited debris came down several kilometers downwind (west of center of burst at Hiroshima and east of center of burst at Nagasaki) and contained isotopes characteristic of fresh bomb debris. If the $t^{-1.2}$ decay low for residual radiation is used, the infinite dose is 1.4 rad at Hiroshima and 30 rad at Nagasaki. The applicability of the $t^{-1.2}$ law to extropolate doses backwards in time is doubtful in this case because of the large amount of precipitation in the intervening 60 days, including that from a typhoon that passed through Southern Japan in mid-September.

Other data from the survey of survivors and their symptoms of radiation sickness suggest that people exposed to rain may have received larger doses than those who were not in the rain.

4. CONCLUSIONS

The conclusions we have reached are that rainout of fresh radioactive debris occurred at Hiroshima and Nagasaki, that this precipitation was initiated either by the weapon itself or by the ensuing fires or by both, and that self-induced rainout can occur and deposit sufficient amounts of radioactivity on the ground to pose a significant collateral damage hazard.

5. ACKNOWLEDGMENT

I would like to thank Frank Murray of the RAND Corporation for providing me with a copy of his cumulus dynamics model. This work was performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore Laboratory under contract no. W-7405-Eng-48.

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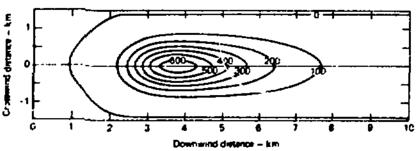

igure 1. Radiation dose rate on the ground one ur after detonation, assuming a 5 m/s wind. tour levels are in rads per hour. A dose of 150 rad/hr is usually considered the hold of militarily significant collateral da

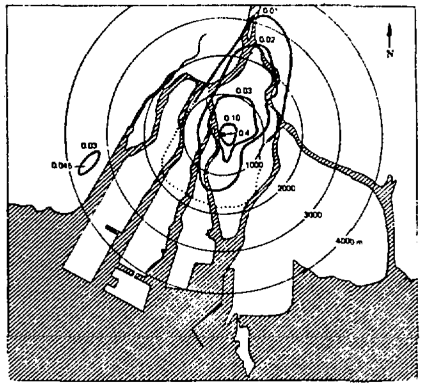

Figure 2. Isodose contours evaluated in milliroentgens per hour for October 3-7, 1945, at Hiroshima.

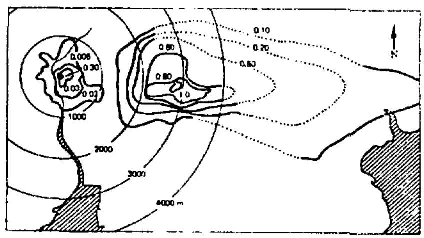

Figure 3. Isodose contours evaluated in milliroentgens per hour for October 3-7, 1945, at Nagasaki.