A PROBABILISTIC EVALUATION OF FALLOUT EFFECTS ASSOCIATED WITH NUCLEAR AIR BURSTS

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INTRODUCTION

Over the past quarter of a century a great deal of theoretical and empirical knowledge concerning atmospheric processes has been developed. Many models attempting to predict atmospheric dispersion effects have been devised, but few have endured, and thus far none has achieved universal applicability, although some have enjoyed widespread popularity. Perhaps among the reasons why most models were or are of limited operational utility is that they failed to adequately incorporate the fact that meteorological and geophysical phenomena are inherently stochastic in nature, and the behavior of such phenomena can be predicted only in statistical terms. Until recently, atmospheric transport models have tended to be deterministic in nature, using estimates of "average" or "worst case" values for computational elements, and have provided for little measure of the probability of occurrence of the predictions. The approach summarized in this paper describes an attempt to remedy that shortcoming, in that it explicitly recognizes the inherent variability of these natural phenomena and attempts to incorporate that variability into a scheme which explicitly quantitates the uncertainty of prediction. It attempts to go a bit further than other approaches to evaluating environmental effects, in that it not only predicts effects but also allows evaluation of the likelihood of occurrence of the predictions.

Fallout from the air burst of a nuclear weapon was chosen as the subject of this initial study because it is of continuing interest in some circles, and a fair body of data exists with which to enumerate parameters and verify accuracy.

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The model is based on the principle that in making a prediction of the amount of fallout to be deposited, and other associated effects resulting from the detonation of a nuclear weapon, one has only an estimate as to how fast the wind might blow, how turbulent the atmosphere might be, etc., and therefore any prediction based upon calculations utilizing any one specific value for each of those phenomena is pertinent to only a very rare combination of events. However, if a very large number of such calculations are made, with the individual element values for each appropriately chosen from the observed probability distributions of values descriptive of the natural phenomena, then a tabulation of the results of all those calculations should give one a good idea of what values of effects are likely, and additionally, how likely they are.

PROCEDURES

The space allotted herein does not allow even a brief description of the details of the model elements, but in general, the computations are performed using rather straightforward and common functions to obtain solutions. A good summary is that the procedure incorporates a very simple computational scheme which can be rapidly calculated many times with various input values of model elements, so that a distribution of results may be examined. At any point during the solution to a problem, values used for many elements of the model are appropriately chosen from probability distribution functions which are empirically descriptive of the corresponding phenomena. Appropriate probability distribution functions were estimated using many data sources: parameters for nuclear weapons-related phenomena were obtained largely from unclassified reports of weapons test activities, while parameters for meteorological and climatological phenomena were derived from numerous scientific publications. At present, model elements include: weapon yield and burst height; nuclear cloud rise, growth, and transport behavior; mass transport phenomena pertinent to ground level radioactivity concentrations and dry deposition; concentrations of radioactive material in the nuclear cloud; wet deposition and depletion of radioactive material from the nuclear cloud resulting from interactions with precipitation systems of variable size, intensity, and probability of occurrence; and estimates of radiation dose rates and doses resultant from occupancy of contaminated areas. Effort has been made to express functional relationships as simply as is possible without sacrificing accuracy or physical significance. The complete solution to a problem consists of calculating the desired effects at selected distances of observational interest, using several thousands of cases, each employing a distinct combination of elements. Upon completion of the calculations, the values of effects to be displayed are bin sorted, and selected percentile values are obtained by interpolation after the bin sort, and printed out. Graphical displays are also prepared, in which equal percentiles of effects vs. distance are plotted.

VERIFICATION EXERCISES, RESULTS, AND CONCLUSIONS

Verification exercises have produced most gratifying results, in that reported measurements of observed effects fall nicely within the modeled distributions of "predicted" effects. To perform these verification exercises, the major sources of data were unclassified reports of fallout monitoring activities available for balloon suspended devices tested during two series of weapons tests conducted in Nevada. Data from twelve tests in one series were used for determining parameters pertinent to test activities, and simulations were made to compare predicted effects with observed effects for eight tests in the other series.

To date, this computer program has been most useful in indicating features of precipitation climates which appear to have important influences upon the environmental effects of atmospheric nuclear weapon deployment.

The methods employed in this analysis appear to have applicability to a wide variety of problems dealing with the evaluation of the environmental consequences of various activities, both nuclear and industrial.