5.10 UNCERTAINTY ANALYSIS WITH MACCS2 USING DATA BASED ON EXPERT ELICITATION[a]

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1. INTRODUCTION

The MACCS2 code (Chanin and Young 1998) is used by the US Nuclear Regulatory Commission (NRC) to make estimates of health and economic consequences resulting from atmospheric releases of radionuclides from a nuclear power plant during a hypothetical accident. The atmospheric transport mechanism used by MACCS2 is a Gaussian plume model with wet and dry deposition. The atmospheric conditions used by the code are sampled probabilistically based on historical site-specific data. The MACCS2 code is not intended to be used to predict consequences from actual releases.

Recent studies at Sandia National Laboratories are using the MACCS2 code to understand the effects of uncertainties in several variables on the results of the analysis. The estimates of uncertainty were developed through an expert elicitation process sponsored by the US NRC and the Commission of European Communities (CEC) (Harper et al., 1995). While the expert elicitation provided estimates of uncertainty for a wide range of parameters, the parameters of concern for this paper are those used to predict atmospheric dispersion for given wind speeds and stability classes.

The MACCS2 code uses a power law relationship to estimate the dispersion of the radiation plume at given distances from the release. A linear term (a) and an exponential term (b) are inputs for the power law equation:

$$s = a\ x^{b} \qquad (1)$$

In the NRC/CEC expert elicitation, estimates of uncertainty were not elicited directly for the linear and exponential terms. Rather, off-centerline to centerline concentration ratios were elicited at various downwind distances for four stability classes and other given conditions such as wind speed and mixing height. The uncertainty estimates for the linear and exponential term of the power law equation (y and z directions) were derived from these elicited values by Delft University using a process called inverse Monte Carlo simulation (Kraan and Cooke, 2000). The uncertainty estimates were cumulative distribution functions for the linear and exponential terms of the power law equation for each of four stability classes plus a correlation matrix.

2. SOME UNCERTAINTIES IN DEVELOPING UNCERTAINTY ESTIMATES

Several factors must be considered when developing an uncertainty estimate for a set of parameters, including assuring the appropriate temporal and spatial scales are represented and correlations between parameters are included. The best case is when sufficient observational or experimental data are available to develop the uncertainty estimate. Often though, there are insufficient relevant data available to estimate an uncertainty distribution and expert judgement is used.

Expert elicitation is a structured process used to collect judgments of several subject matter experts and transform them into usable uncertainty distributions. There are three main areas where uncertainties enter into the uncertainty distributions developed by expert elicitation:

- Selecting the variables to be elicited
- Deciding how to pool results of various experts
- Transforming elicited values to model parameters

The least uncertain case is when the parameter under consideration can be estimated directly. However, if the parameters under consideration have little physical meaning, such as the linear and exponential terms of the power law equation, expert judgements are more difficult to elicit. In these cases, related parameters with more physical meaning (i.e., off-centerline to centerline concentration ratios for given distances) are frequently elicited. This is a tradeoff between the advantage of being able to more consistently elicit a parameter and the disadvantage of having to transform that parameter to the one of interest.

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Expert elicitation is used when there are insufficient relevant data with which to make informed judgements on uncertainty distributions. Typically, several experts are elicited and their resulting estimates are pooled. Equal weights are typically assigned to each expert's judgements unless some method can be developed to give greater weight to some experts than others.

Uncertainty in the parameter estimate is increased when the estimates from the experts differ widely. For example, if five equal weight expert estimates are 10, 12, 15, 18, and 100, the resulting mean value of 31 is highly influenced by the one estimate of 100 and the relative agreement of the remaining four experts is not explicitly considered.

Uncertainties resulting from transforming elicited variables into model parameters can be the most difficult to understand. The mathematical process used by Delft to transform elicited variables to model parameters required a specialized expertise in applied mathematics not common among meteorologists and engineers.

3. CHECKS FOR REASONABLENESS OF UNCERTAINTY ESTIMATES

There are several ways to assess whether an uncertainty distribution is a reasonable representation of reality. One of the most crude but effective methods of identifying suspect distributions is to use them in a computer code and evaluate the results. This method detected problems with preliminary uncertainty estimates when the MACCS2 code returned physically unreasonable estimates. This method is not a systematic way to detect problematic distributions and will only detect extreme problems.

Expert review of the distributions is an excellent method for assessing the reasonableness of uncertainty distributions. The subject matter expert can review the resulting uncertainty distribution within the context of the specific problem and apply his unique intuition, expertise and knowledge of relevant information and analysis to the problem.

Additionally, he can incorporate input from expert colleagues. For this project, one of the authors conducted an informal elicitation of nine meteorology experts on the 95% confidence interval of the y- and z-direction dispersion coefficients for short-range dispersion. There was consensus that both dispersion values ranged over about one order of magnitude.

The primary disadvantage of expert review is the additional time and cost associated with these additional reviews.

Sometimes experimental data are available to augment expert elicitation. For example, field data used to develop the dispersion coefficients for the Pasquill-Gifford stability classes (Draxler, 1984) indicate a 95% confidence interval of about one order of magnitude for both the y- and the z-dimension dispersion.

These informal elicitation results and field data match well with the Delft estimates for the y-direction dispersion but are considerably less than the Delft estimate for the z-direction dispersion. We suspect that this difference is an artifact of the Delft approach that calculated the z-direction dispersion without specifically eliciting expert opinion on this parameter. These field data and informal elicitation results will be used to modify the z-dimension dispersion uncertainty distribution in future uncertainty studies for the US NRC.

4. CONCLUSIONS

Results of uncertainty analyses are highly dependant on the values for input distributions. Caution should be used when accepting uncertainty distributions provided by others or from sources that are not fully understood.

To help build confidence, the distributions should be compared to relevant data as a consistency check and, if time and funding allow, a subject matter expert should be consulted. Consistent with good engineering practice, the time to discover problems with data is before the analysis is complete.

5. REFERENCES

Channin D. and M. Young. 1998. Code Manual for MACCS2: User's Guide. NUREG/CR-6613, Vol.1; SAND97-0594. Albuquerque, New Mexico.

Draxler, R.R., 1984. Diffusion and Transport Experiments, Chapter 9 in Atmospheric Science and Power Production (D. Randerson, ed.), DOE/TIC-27601 (DE84005177), USDOE, 367-422.

Harper F. *et al*. 1995: Probabilistic Accident Consequence Uncertainty Analysis. NUREG/CR-6244;EUR 15855EN; SAND94-1453 Vol.1. US Nuclear Regulatory Commission and Commission of European Communities. Albuquerque, New Mexico.

Kraan, B. and R. Cooke. 2000. Processing Expert Judgements in Accident Consequence Modeling. Radiation Protection Dosimetry 90(3), 311-315.