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MACCS versus GENII

Code Comparison

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1. GENII Installation

GENII Version 1.473 was installed on a PC at Technadyne Engineering Consultants, Inc. in August 1991. That version, while not the most recent, is the same as was used by DOE for the 1991 Draft Environmental Impact Statement on New Production Reactor Capacity.

2. MACCS Weather File

A MACCS weather file for Hanford was obtained from Sandia National Laboratories. That file was used by Sandia in the 1990 N-Reactor PRA. It is being provided to LANL on a floppy disk.

3. Utility Programs for Weather Data

Several utility programs for weather file conversion and comparison were written during the project. These allow preparation of a GENII Joint Frequency file from MACCS weather data and removal of rain data from MACCS files so that MACCS and GENII could be run using the same fundamental weather database. These programs, in GWBASIC, are being transmitted to LANL on a floppy disk. User documentation and program listings are being provided to LANL.

Two steps were taken to validate program JFPREP. JFPREP was used to prepare a Joint Frequency file with wind speed breakpoints matching those hard-wired into MACCS using the weather file described in Section 2. The resulting Joint Frequency file was compared to the MACCS output table labeled "BIN WINDROSE SUMMARY" after making corrections for wind direction indices (from versus to) and the MACCS bin definitions. This comparison showed that JFPREP processed the 8760 hourly readings of the weather file in a manner equivalent to MACCS.

JFPREP was also used to prepare a file based on the above weather data using the same breakpoints as included in the sample Joint Frequency file supplied with Version 1.473 of GENII. Sample Problem One of GENII was run with this file so that results for this problem with the GENII Sample Problem five years of weather data and the single year of data could be compared. These runs reported doses of 6.3E-04 and 6.2E-04 Sv, respectively, serving as validation of the data handling of JFPREP.

4. Base Case Input Data for MACCS and GENII

Input for the MACCS vs GENII comparison was prepared using the source term from LANL file HW101-SY.INP, run dated 2/19/91. That source term was modified by removing Tc-99 since MACCS includes dose conversion factors for Tc-99m but not for TC-99. The seven nuclides in the source term are: Sr-90, Cs-137, Pu-239, Pu-240, Am-241, I-129, and Np-237. The release was assumed to be a point source at ground level with a 10 minute release duration. Doses were calculated at a distance of 660 meters with an exposure duration of two hours. A GENII Joint Frequency file was prepared from the MACCS weather file using the same windspeed breakpoints as are hard-wired into MACCS. Program JFPREP was developed for this purpose. A User Manual for this code was prepared as documentation and has been included with this report.

5. Analysis of Base Case Results

Several preliminary runs of both MACCS and GENII for the Base Case using the MACCS weather data for the year 1986 indicated that the 95th quantile doses reported by GENII were higher than those of MACCS. Several factors were investigated to determine the cause of that difference.

The two codes differ in how they treat wind direction. GENII calculates a 95th quantile dose associated with a particular wind direction while the MACCS dose is not associated with any particular wind direction. For purposes of comparison GENII was run for all sixteen possible wind directions. The results are tabulated in the following table:

TABLE I GENII Results

GENII Wind Direction	Dose (Sv)
1	4.8E-04
2	4.5E-04
3	4.1E-04
4	2.9E-04
5	3.4E-04
6	2.0E-04
7	1.9E-04
8	3.8E-04
9	5.0E-04
10	4.6E-04
11	4.3E-04
12	4.4E-04
13	4.6E-04
14	5.0E-04
15	4.6E-04
16	4.9E-04

Average = 4.05E-04 (Sv)
Variance= 0.78E-04 (Sv)

Although it was noted that there is significant variability of the GENII results by wind direction, the above average was used for the Base Case for GENII. With comparable input data the result reported by MACCS was 1.33E-04 Sv. Further work was necessary to explain why GENII calculated a dose three times higher than MACCS.

To simplify the analysis, a constant weather, single nuclide run was set up with both codes. Additional input files were prepared to represent a problem consisting of a single nuclide, Cs-137, and a constant wind speed of 1.32 m/s with F-stability. Results for the two weather assumptions for both Cs-137 and the seven nuclide source term are summarized in the following table:

TABLE II MACCS vs GENII Initial Results

$$\frac{\text{GENII Dose (Sv)}}{\text{MACCS Dose (Sv)}} = \text{Difference Factor}$$

	7 Nuclide Source Term	Cs-137 Source Term
1986 Weather Data	$\frac{4.1E-04}{1.33E-04} = 3.0$	$\frac{5.6E-05}{3.05E-05} = 1.8$ **
Constant 1.32 m/s F-Stab	$\frac{2.6E-04}{1.36E-04} = 1.9$	$\frac{3.6E-05}{2.44E-05} = 1.5$

**(GENII was run only for wind direction 15 for this case. The calculated dose of 6.3E-05 was scaled by the ratio 4.1/4.6 based on the values in TABLE I to adjust for wind direction averaging)

Some of the differences above are due to known differences in the MACCS and GENII models and parameters.

1) Since for this exposure scenario the dose is due almost entirely to inhalation, the parameters defining that pathway in both codes were compared. The breathing rate used by GENII (2.70E-04 m^3/s) is 1.5% higher than that that for MACCS (2.66E-04 m^3/s).

2) Dose conversion factors in GENII appear to be higher than those used in MACCS. A comprehensive one to one comparison was not possible due to time constraints, however the GENII dose conversion factor for Cs-137 for small intestine was found to be 0.98E-08 Sv/Bq in GENII's debug output. The comparable value used in MACCS is 0.904E-08 Sv/Bq. Thus the GENII value is about 8% higher than that for MACCS.

3) Both MACCS and GENII use the Pasquill-Gifford-Turner (PGT) curves to estimate diffusion coefficients. However, some differences in the constants used by each code in these calculations result in MACCS simulating a plume about 59% larger in the vertical dimension than does GENII for E-stability and 25% larger for F-stability.

The above noted factors can be combined into total difference factors of about 1.7 for E-stability and 1.4 for F-stability. These account for most of the differences shown in TABLE II.

It is reasonable to suppose that the presence of long-lived nuclides (such as plutonium) in the source term is resulting in the larger difference factor for the full source term. Due to biological clearance mechanisms Cs-137 is gone from the body after three years while plutonium remains for the entire fifty year committment period. This would lead to a higher degree of conservatism in the GENII dose factors for long-lived nuclides, since the calculational method used by GENII is known to be less precise than the method used for MACCS.

For the two constant weather cases the difference between GENII and MACCS results can be explained as a result of differences between parameters used by the two codes. There still remains the question of why that difference is larger when a year of weather is used. Any impact of differences in the atmospheric and dosimetric data should affect both types of calculations in roughly the same way. If we assume that the atmospheric and dosimetric models of MACCS and GENII can be considered equivalent, it is still necessary to explain the difference factor of 3.0 from TABLE II when the two 95th quantile doses are compared.

6. Analysis of MACCS Variability for the Year of Weather

For representation of the given year of weather, MACCS and GENII use statistical sampling techniques which are quite different. The 95th quantile dose is estimated from a distribution of doses calculated using a structured Monte Carlo (that is, Latin Hypercube) approach. The user input file for MACCS specifies an initial value for the random number generator and 95th quantile doses can vary somewhat when different initial values are utilized. Given the fact that MACCS uses random sampling, it was necessary to determine the variability of MACCS results when different values are used as the "seed" of its random number generator.

MACCS was used to rerun the seven nuclide case with 1986 weather data six times, each with a different random seed. These results are presented in the following table:

TABLE III MACCS Variability for Different Random Seeds

Run	Random Seed	MACCS Dose (Sv) 95th quantile	Observed Peak
1	82	1.74E-04	3.24E-04
2	67	1.33E-04	3.24E-04
3	87	1.33E-04	3.24E-04
4	73	1.51E-04	3.24E-04
5	63	1.33E-04	3.24E-04
6	91	1.33E-04	3.24E-04
	Average =	1.43E-04	
	Variance=	0.13E-04	

Using this average, 1.4E-04 for MACCS, and the GENII value of 4.1E-04 results in 2.9 for the difference factor in TABLE II. From these six calculations there is no indication that MACCS sampling variability is the reason for MACCS being higher than GENII.

7. Analysis of GENII Variability for the Year of Weather

The 95th quantile dose from GENII can also vary depending on the statistical sampling parameters selected by the user. For this code, the significant parameter is the set of windspeed breakpoints used to generate the Joint Frequency table.

For the GENII run shown in TABLE II for 1986 weather and seven nuclides these breakpoints were chosen to match those hard-wired into MACCS. But JFPREP.BAS allows the user to define arbitrary windspeed breakpoints so that several different GENII Joint Frequency tables can be produced from the same MACCS data, namely HAN86MET.DAT the 1986 weather data. GENII was run four more times with the following breakpoints and results:

TABLE IV GENII Variability
for Different Windspeed Breakpoints

File Name	Windspeed Breakpoints 1	2	3	4	5	6	7	8	95th Quantile Dose (Sv)
JFCRS.DAT	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	4.6E-04
JFMED.DAT	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	3.7E-04
JFFIN.DAT	.25	0.5	.75	1.0	1.25	1.5	1.75	2.0	3.7E-04
JFNRC.DAT	2.0	4.0	6.0	8.0					2.7E-04

The last Joint Frequency file utilizes breakpoints representing the minimum resolution required by the NRC for on-site meteorological programs at commercial power plants. The above four doses have an average value of 3.3E-04 Sv. There is no clear pattern between calculated dose and resolution of the breakpoints. The influence of breakpoint choice could thus be considered a type of sampling variability analogous to the MACCS variability shown in Section 7.

8. Final Analysis

The average dose for MACCS of 1.43E-04 (found in Section 6) and the dose of 3.3E-04 (found in Section 7) result in a difference factor of 2.3. The code differences discussed above for breathing rate, dose factor, and PGT parameters may account for a difference ratio of up to 1.7 (i.e. 70%). The final, as yet unexplained, difference factor between the GENII and MACCS results can then be estimated as 2.3/1.7=1.3 (i.e. 30%) which represents good agreement considering the numerous differences between the two codes.

9. Conclusions

There are substantial differences between the GENII code and its model and those of MACCS that make a precise comparison difficult. Further comparative scenarios could be developed, with simple source terms, to pinpoint the source of differences in the calculations. A complete comparison of dose conversion factors could be helpful in identifying what source terms to use for more extensive comparative analyses. This exercise doesn't represent a rigorous benchmarking of the two codes but does indicate that a precise explanation of all observed differences could be obtained with some additional work.

The results obtained in this exercise indicate that GENII is more conservative than MACCS. GENII is intended to be used for demonstrating compliance with environmental standards which can represent fixed upper limits for operation of a facility. The potential costs of an inadvertent underestimation of impacts by GENII could be quite large, with the possibility of facility shutdown and/or redesign. For that reason, GENII results are intended, by and large, to represent conservative bounds on consequences.

Because MACCS has evolved out of PRA, where significant value is attached to realistic estimates, it has less of a conservative bias than GENII. The MACCS code, in its present form, is not intended for use in evaluating compliance with environmental standards such as the 25 rem dose at the exclusion boundary.

Therefore it is not at all surprising that GENII results are more conservative than those of MACCS.

After considering the differences between the two code's assumptions, there still remains about a 30% difference in results not fully explained. Further efforts could possibly reduce this margin, though, in the absence of a clear need, it is not obvious that such efforts are advisable.