Impact of Increased Latent Generations on Sensitivity Calculations with SCALE*

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ABSTRACT

Analyses of cross section sensitivity data from systems with fissile material allow analysts to associate an importance for each material, nuclide, reaction, and neutron energy by simulating real-world criticality scenarios. Although criticality safety validation efforts can be guided by the cross section sensitivity and uncertainty data generated for a particular system, these calculations can often be computationally expensive and sometimes cumbersome without proper guidance. The TSUNAMI suite within the SCALE code package has several methods for generating sensitivity data, including multigroup and continuous energy (CE) capabilities. The release of SCALE 6.3 has three different CE methods for generating cross section sensitivity data: (1) the Iterated Fission Probability (IFP) method with the KENO Monte Carlo transport solver, (2) the IFP method with the Shift Monte Carlo transport solver, and (3) the Contributon-Linked eigenvalue sensitivity/Uncertainty estimation via Tracklength importance CHaracterization (CLUTCH) method with the KENO Monte Carlo transport solver. Although the CLUTCH method has additional parameters for generating sensitivity data files relative to the IFP method, all three methods use latent generations, which are the generations between an event (i.e., fission) and the assessment of importance based on the asymptotic population of progeny neutrons. Increasing the number of latent generations in a calculation leads to increased discrimination of the sensitivity coefficients but at the cost of the increased uncertainty associated with those generated values. Analysts must balance the accuracy of the sensitivity calculations and its uncertainty with the associated computational cost involved in generating the values. This paper discusses the impact of adjusting the latent generation parameter for a range of sensitivity values and how these changes compare with the direct perturbation values obtained from a change of ±0.5% Δ*k* in both benchmark and safety application models. Two benchmarks from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* and the MPC-32 dual purpose canister for spent nuclear fuel are used for analysis.

Key Words: latent generations, SCALE, sensitivity

1 INTRODUCTION

Analyses of cross section sensitivity data from systems with fissile material allow analysts to associate an importance for each material, nuclide, reaction, and neutron energy by simulating real-world criticality scenarios. Although criticality safety validation efforts can be guided by the cross section sensitivity and

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uncertainty data generated for a particular system, these calculations can often be computationally expensive and sometimes cumbersome without proper guidance. The TSUNAMI suite within the SCALE code package has several methods for generating sensitivity data, including multigroup and continuous energy (CE) capabilities [1]. The generated sensitivity data files, which contain all energy-dependent sensitivity data for a model, represent the sensitivity of k_{eff} to each constituent piece of nuclear data used for the calculation.

The release of SCALE 6.3 provides three different CE methods for generating cross section sensitivity data: (1) the Iterated Fission Probability (IFP) method with the KENO Monte Carlo transport solver, (2) the IFP method with the Shift Monte Carlo transport solver, and (3) the Contributon-Linked eigenvalue sensitivity/Uncertainty estimation via Tracklength importance CHaracterization (CLUTCH) method with the KENO Monte Carlo transport solver [1]. To determine whether the sensitivity data generated are correct, direct perturbation (DP) calculations are used to confirm sensitivities of the most important nuclides. However, there are instances in which the DP- and TSUNAMI-generated sensitivities do not agree, and, as noted in a TSUNAMI 3D case study, it is desirable for the differences between the two calculations to be less than 5%, less than 0.01 in absolute sensitivity, and/or less than 2 standard deviations using combined uncertainties [2]. For CE sensitivity calculations, especially with the IFP method, the only parameter available for fine tuning sensitivities is the number of latent generations.

Although the CLUTCH method has additional parameters for generating sensitivity data compared to the IFP method, all three methods use latent generations, which are the generations between an event (i.e., fission) and the assessment of importance based on the asymptotic population of progeny neutrons [1]. Although increasing the number of latent generations in a calculation result in increased discrimination of the sensitivity coefficients, there is a cost of increased uncertainty associated with those generated values. Thus, analysts must balance the accuracy of the sensitivity calculations and its uncertainty with the associated computational costs involved in generating the values. This paper discusses the impact of adjusting the latent generation parameter for a range of sensitivity values and how these changes compare with the DP values obtained from a change of ±0.5% Δk in both benchmark and safety application models.

2 METHODOLOGY

Two benchmarks from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (ICSBEP Handbook) [3] were selected for demonstration purposes and analysis: PU-MET-FAST-001-001S (PMF-001-001S) and LEU-COMP-THERM-008-006 (LCT-008-006). These experiments along with the MPC-32 dual purpose canister for spent nuclear fuel [4] applications were selected to demonstrate the behavior associated with adjusting the latent generation parameter for a range of sensitivity values. The two benchmark experiments were taken directly from the Verified, Archived Library of Inputs and Data (VALID) [5] available from ORNL using KENO V.a geometries, while the MPC-32 dual purpose canister model was developed by J. Clarity using KENO-VI geometry [4] via the TSUNAMI-3D sequence in SCALE 6.3.beta15.

Each nominal benchmark calculation that used IFP with KENO and Shift comprised of 10,000 total generations—100 of which were discarded—with 10,000 particles per generation. The CLUTCH calculations with the benchmark experiments comprised of 11,000 total generations—1,000 of which were discarded—with 10,000 particles per generation and a 2 cm uniform mesh for the F*(r) calculation. For the MPC-32 canister model, only the IFP-Shift and CLUTCH methods were examined because the large number of materials and geometric units causes an extremely large memory footprint for the IFP-KENO calculation. The IFP-Shift and CLUTCH methods can take advantage of parallel processing with multiple computer nodes, which is unavailable for IFP-KENO calculations. The IFP-Shift calculations consisted of 550 total generations—150 of which were discarded—with 50,000 particles per generation, and the

CLUTCH calculations consisted of 2,000 total generations—500 of which were discarded—with 50,000 particles per generation and a user-defined mesh for the F*(r) calculation [6]. All calculations used the continuous energy ENDF/B-VII.1 library [7].

Sensitivity coefficients were generated for each critical experiment and canister input by specifying the calculational method with the `cet=` parameter and the number of latent generations with the `cfp=` parameter. For IFP-Shift or -KENO calculations, `cet=2`, and for CLUTCH calculations, `cet=1`. The `cfp` parameter was set to 3, 5, 10, 20, 30, 40, and 50 to examine the impact of latent generation adjustments on the TSUNAMI-generated sensitivity coefficients. For each method and number of latent generations, five calculations were performed and then the energy-integrated sensitivities were averaged to account for minor statistical fluctuations or noise inherent in Monte Carlo calculations. IFP-KENO with LCT-008-006 only used one calculation because of the very long calculational time. The models presented in Table I are arranged in increasing complexity and offer a wide range of sensitivity values and energy ranges to demonstrate the effect of adjusting the number of latent generations used in a calculation. Table I provides the DP sensitivity values that are used as a baseline for analysis in this report. Although there are multiple nuclides with sensitivities that are generally examined as part of confirmatory analysis, only a select few are examined here for brevity.

Table I. Baseline DP Sensitivities for Select Nuclides

		Monte Carlo Transport Solver			
		KENO		Shift	
Case	**Nuclide**	**Sensitivity**	**Uncertainty**	**Sensitivity**	**Uncertainty**
PMF-001-001S	^{239}Pu	0.8204	0.0019	0.8219	0.0019
	^{240}Pu	0.0286	0.0004	0.0281	0.0003
LCT-008-006	^{1}H	0.1014	0.0015	0.1018	0.0018
	^{235}U	0.3272	0.0018	0.3278	0.0019
	^{238}U	-0.1324	0.0019	-0.1354	0.0017
MPC-32*	^{1}H	0.1456	0.0016	0.1433	0.0017
	^{235}U	0.2147	0.0017	0.2137	0.0018
	^{238}U	-0.1133	0.0015	-0.1120	0.0017
	^{239}Pu	0.0788	0.0015	0.0763	0.0014

*Only CLUTCH and IFP-Shift calculations.

3 RESULTS

3.1 PMF-001-001S

PMF-001-001S is the simplified version of the Jezebel critical assembly that demonstrates sensitivities for a fast, metal system, and as noted in Table I, the two DP sensitivities selected for analysis are ^{239}Pu and ^{240}Pu. These sensitivities are at the far ends of the coefficient range of magnitudes with ^{239}Pu exceeding 0.8 and ^{240}Pu just under 0.03. The largest sensitivity coefficients encountered typically result from fast metal benchmark systems with largely ^{239}Pu or ^{235}U and are on the order of 0.8. Coefficients below 0.02 are generally not considered for confirmation with direct perturbation calculations given their weak effect on k_{eff} and difficulty overcoming DP uncertainty. Figure 1 provides the effect of increasing the number of latent generations for this system with all three methods (blue circles for IFP-Shift, red squares for IFP-KENO, and green diamonds CLUTCH). For all sensitivity figures listed, the dotted purple line is the baseline DP-Shift values for the associated nuclide, and the dashed purple lines are the 1σ uncertainty bands. The black dotted line is the baseline DP-KENO values, and the dashed black lines are the 1σ uncertainty bands. The generated DP sensitivity values generated with KENO and IFP in Table I are statistically equivalent to each other.

The plot on the left in Figure 1 for ^{239}Pu shows that the IFP-Shift sensitivities (blue circles) fall just outside of the DP-Shift 1σ uncertainties (dashed purple lines) after three latent generations. The IFP-KENO sensitivities (red squares) fall completely outside of the DP-KENO 1σ uncertainties (dashed black lines) for all latent generations but are in good agreement with the IFP-Shift results. The CLUTCH sensitivities (green diamonds) all fall inside of the DP-KENO 1σ uncertainties. In fact, the CLUTCH sensitivities are in excellent agreement with the DP sensitivity value with little fluctuation as a function of number of latent generations. There is a statistical difference between 3–5 latent generations for IFP-Shift and CLUTCH, and between 3–5 and 5–10 for IFP-KENO; however, differences beyond these points are trivial even though there appears to be slight positive (IFP-KENO) or negative (IFP-Shift) trend. Additionally, only CLUTCH sensitivities have a statistical difference between 3–50 generations, although the IFP methods approach significance.

The plot on the right side of Figure 1 for ^{240}Pu shows that all sensitivity values for IFP-Shift (blue circles) fall outside of the DP-Shift 1σ uncertainties (dashed purple lines), whereas the IFP-KENO and CLUTCH sensitivities (red squares and green diamonds, respectively) all fall within the DP-KENO 1σ uncertainties (dashed black lines). Again, the two IFP results are in good agreement. The IFP-Shift results are only slightly outside the 1σ band of the DP-Shift result. The two DP results are also within approximately 1σ of each other, so there is reason to suspect the DP-Shift result may be slightly low. The increase in uncertainty is also observed more directly in the IFP calculations as the number of latent generations is increased. While the uncertainties overlap for ^{240}Pu and IFP—meaning they are statistical equivalent or within 1σ—these differences become more pronounced with ^{239}Pu as the latent generations increase. There is a statistical difference between 3–5 latent generations for IFP-KENO and CLUTCH, as well as between 3–50 for CLUTCH; all IFP-Shift differences are insignificant.

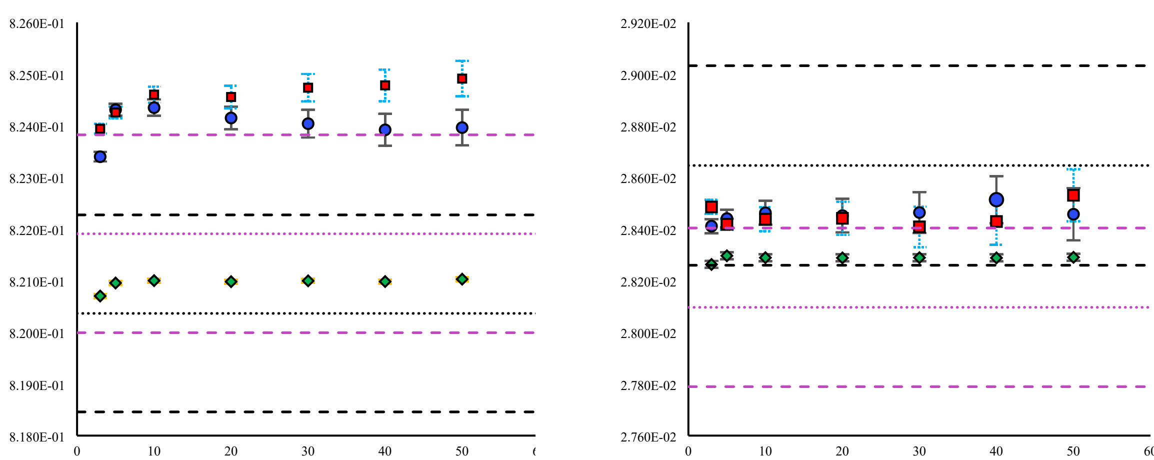

Figure 1. PMF-001-001S sensitivity coefficients by number of latent generations: ^{239}Pu (left) and ^{240}Pu (right). Blue circles are IFP-Shift, red squares are IFP-KENO, and green diamonds are CLUTCH. Purple dashes are Shift DPs and 1σ bands, and black dashes are KENO DPs and 1σ bands.

As a general observation, the CLUTCH sensitivities for this type of system appear to be invariant to the `cfp` parameter and are lower in value than the IFP counterparts, although all generated sensitivities are within the accepted differences from the DP values, as described in [2]. The impact of latent generations should be smaller in the CLUTCH methodology as it only impacts the F*(r) importance function but does not directly influence the calculated sensitivities. For simple, fast systems such as this, analysts can use a method of choice with a few latent generations for sensitivity analysis given the small memory footprint and runtimes associated with these calculations and the small differences between the DP and calculated sensitivities.

3.2 LCT-008-006

LCT-008-006 is a critical experiment of a lattice of low-enriched UO_2 fuel rods with Pyrex control rods and borated water meant to closely resemble a pressurized water reactor (PWR) assembly [3]. Three sensitivities were selected for analysis: ^{1}H in the coolant (0.1014 ± 0.0015 [KENO] and 0.1018 ± 0.0018 [Shift]) and ^{235}U (0.3280 ± 0.0026 [KENO] and 0.3274 ± 0.0030 [Shift]) and ^{238}U (-0.1324 ± 0.0019 [KENO] and -0.1354 ± 0.0017 [Shift]) in the fuel rods. Figure 2 provides the effect of increasing the number of latent generations for this system with all three methods.

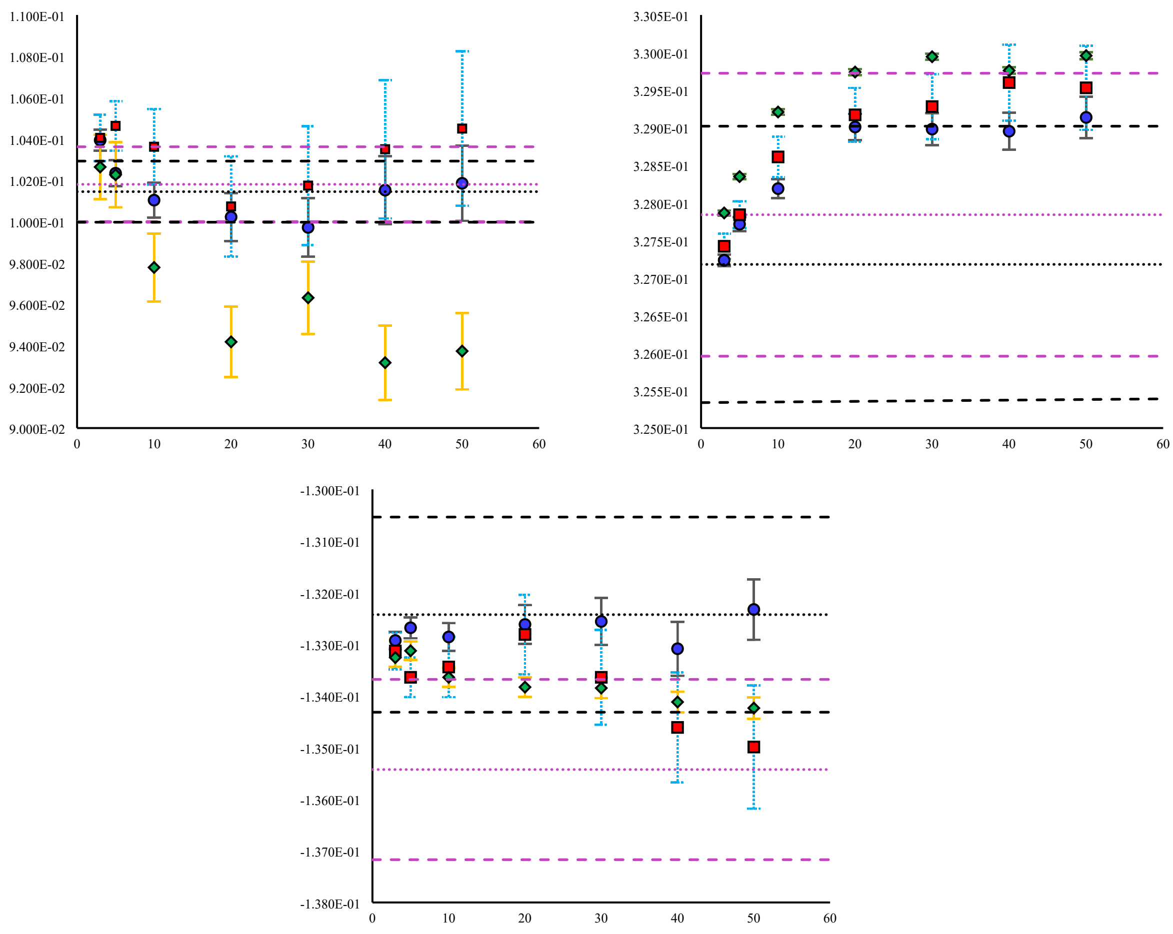

Figure 2. LCT-008-006 sensitivity coefficients by number of latent generations: ^{1}H (upper left), ^{235}U (upper right), and ^{238}U (lower center). Blue circles are IFP-Shift, red squares are IFP-KENO, and green diamonds are CLUTCH. Purple dashes are Shift DPs and 1σ bands, and black dashes are KENO DPs and 1σ bands.

The plot of ^{1}H (upper left) in Figure 2 shows that the sensitivity results for IFP-Shift (blue circles) and IFP-KENO (red squares) are "u-shaped" with minima at 20 (IFP-KENO) and 30 (IFP-Shift) latent generations near the lower uncertainty band for the respective DP values (dashed purple and black lines). The CLUTCH results appear to have a continuously decreasing trend until 20 latent generations. There is no statistically significant difference between each successive calculation nor between 3–50 latent generations for IFP-KENO (red squares), although the difference between 10–20 latent generations approach significance. For IFP-Shift (blue circles) there are statistical differences between 3–5, 5–10, and 3–50 latent generations, and for CLTUCH (green diamonds) between 5–10, 10–20, 30–40, and 3–50 latent generations. The difference between 20–30 latent generations for CLUTCH approach the 1σ difference. Beyond 10 latent generations, the differences between the CLUTCH and DP-KENO sensitivities fall beyond the acceptable criteria as noted in [2]. The cause for the inconsistencies in the CLUTCH calculations with ^{1}H must be related to the elastic scattering reaction which accounts for nearly all the ^{1}H sensitivity.

For ^{235}U (upper right) in Figure 2, there is a clear trend of increasing sensitivity values before leveling off after approximately 20 latent generations. It is also interesting to note that there is excellent agreement on the sensitivity for this nuclide with all three methods as the number of latent generations increase. All sensitivity calculations for IFP-Shift are less than 1σ of the DP-Shift values (blue circles and purple lines), while the IFP-KENO and CLUTCH sensitivity calculations fall just outside of the upper 1σ DP-KENO uncertainty band (dashed black lines) after 10 latent generations for IFP-KENO (red squares) and after 5 latent generations for CLUTCH (green diamonds). For both IFP methods there are statistical differences between 3–5, 5–10, 10–20, and 3–50 latent generations, and for the CLUTCH method (green diamonds) there are statistical differences between all successive calculations, including 3–50 latent generations.

Although there is generally good agreement across all three methods, the plot for ^{238}U in Figure 2 (lower center) also has an irregular pattern regarding the calculation of sensitivities with each method, like that found with ^{1}H. The IFP-Shift (blue circles) sensitivity values are generally unchanging and statistically similar with an underprediction of the sensitivity relative to the DP-Shift result (purple lines). While there is somewhat of a visual trend away from the upper 1σ DP-Shift uncertainty band, there is no statistical difference between 3 and 50 latent generations. The sensitivities calculated with IFP-KENO (red squares) and CLUTCH (green diamonds) have a decreasing trend away from the DP-KENO result (black lines) towards and beyond the lower 1σ uncertainty band, most likely from the largest contributor for the ^{238}U sensitivity, the (n, γ) capture reaction. For IFP-KENO there is a significant difference between 3–50 latent generations, and for CLUTCH between 5–10 and 3–50 latent generations. A final, general observation is that the uncertainty for the IFP calculations dramatically increases as the number of latent generations increase. While the uncertainties in the CLUTCH sensitivity do increase, they are not as pronounced as those with the IFP calculations. The CLUTCH calculations use latent generations in the determination of the F*(r) importance function, but not directly in the determination of the sensitivity. This acts to reduce the impact of increased latent generations on the uncertainty in the CLUTCH calculations.

As for ^{235}U and ^{238}U, both nuclides meet acceptance criteria at all latent generations for each calculational method. In general, the IFP calculations appear to generate more accurate sensitivity coefficients than CLUTCH for a typical PWR thermal system, regardless of the number of latent generations.

3.3 MPC-32 CANISTER

The model in Figure 3 is a Holtec MPC-32 Dual Purpose Canister (DPC). DPCs are licensed for storage and transportation and rely upon installed neutron absorbers to demonstrate subcriticality. Currently, DPCs are being investigated for disposal in a geologic repository. A significant challenge associated with directly disposing of DPCs is the potential for the neutron absorber to degrade during the repository performance period. In order to address the loss of neutron absorber, criticality analyses have been performed that take credit for the as-loaded configuration of DPCs. These models have unique compositions for each of the 18 axial nodes in each of the 32 radial basket cells. For this DPC each fuel location is occupied by a Westinghouse 17 × 17 Standard fuel assembly [4]. These highly heterogeneous models represent a significant challenge for sensitivity calculation methods.

As noted earlier, due to the size and complexity of the canister input and the amount of memory needed for a serial IFP-KENO, calculation, only IFP-Shift and CLUTCH calculations were used to generate sensitivity coefficients. While several nuclides were identified with sensitivities greater than 0.02, only the four largest were selected for analysis: ^{1}H, ^{235}U, ^{238}U, and ^{239}Pu. These sensitivity values are summed across all mixtures for the total sensitivity per nuclide. Figure 4 provides the effect of increasing the number of latent generations for this system with the IFP-Shift and CLUTCH methods.

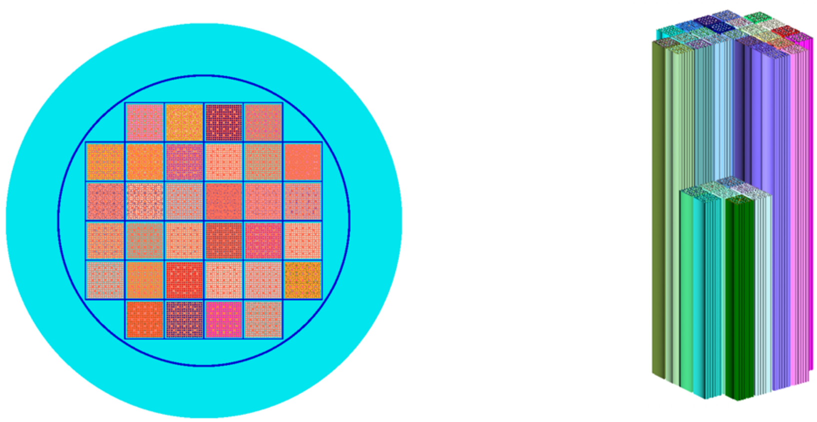

Figure 3. Radially (left) and axial (right) view of the MPC-32.

The plot of the four sensitivity coefficients by the number of latent generations reveal that both the IFP-Shift and CLUTCH methods generate similar values for each of the selected nuclides. Unlike the plots for LCT-008-006 with ^{1}H and ^{238}U where there are irregularities in the trending, all four nuclides have clear trends for the MPC-32 canister: the ^{1}H and ^{238}U plots trend upward with increasing latent generations, while ^{235}U and ^{239}Pu trend downward. Also, only a few nuclide-latent generation combinations have differences greater than 1σ (uncertainty bands not overlapping), indicating similar sensitivity values for both calculational methods. It is interesting that while both the MPC-32 canister and LCT-008-006 have similar energy of average lethargy of fission (EALF) values (~0.25 to 0.29 eV), the plots for ^{1}H and ^{238}U are relatively more stable in comparison. This is not to say that the two models are similar, only that in comparison to another thermal system, the MPC-32 canister sensitivity coefficients have less variability with increased latent generations than those of LCT-008-006.

The plot of ^{1}H sensitivity (upper left) in Figure 3 shows that the results for both IFP-Shift and CLUTCH are outside of the 1σ DP uncertainty bands. However, as the number of latent generations increase, the sensitivity values begin to approach these bands. For IFP-Shift (blue circles) there are statistical differences between 3–5, 10–20, and 3–50 latent generations. For CLUTCH (green diamonds) the sensitivities peak at 40 latent generations with all differences between successive calculations (including 3–50) statistically significant, except 3–5 and 10–20 latent generations.

The plot for ^{235}U (upper right) in Figure 4 shows relatively stable sensitivity calculations for both methods with a significant difference found between 10–20 latent generations for IFP-Shift (blue circles). For CLUTCH, except for 3–5 and 30–40 latent generations, all successive differences are statistically significant, including 3–50 latent generations. Both methods generate values that fall within the 1σ uncertainty bands, with the CLUTCH calculations hovering around the DP-KENO value (dotted black line) from 20 latent generations onward and the IFP-Shift (blue circles) values coming closest at 20 latent generations but falling comfortably within the 1σ uncertainty band in all cases.

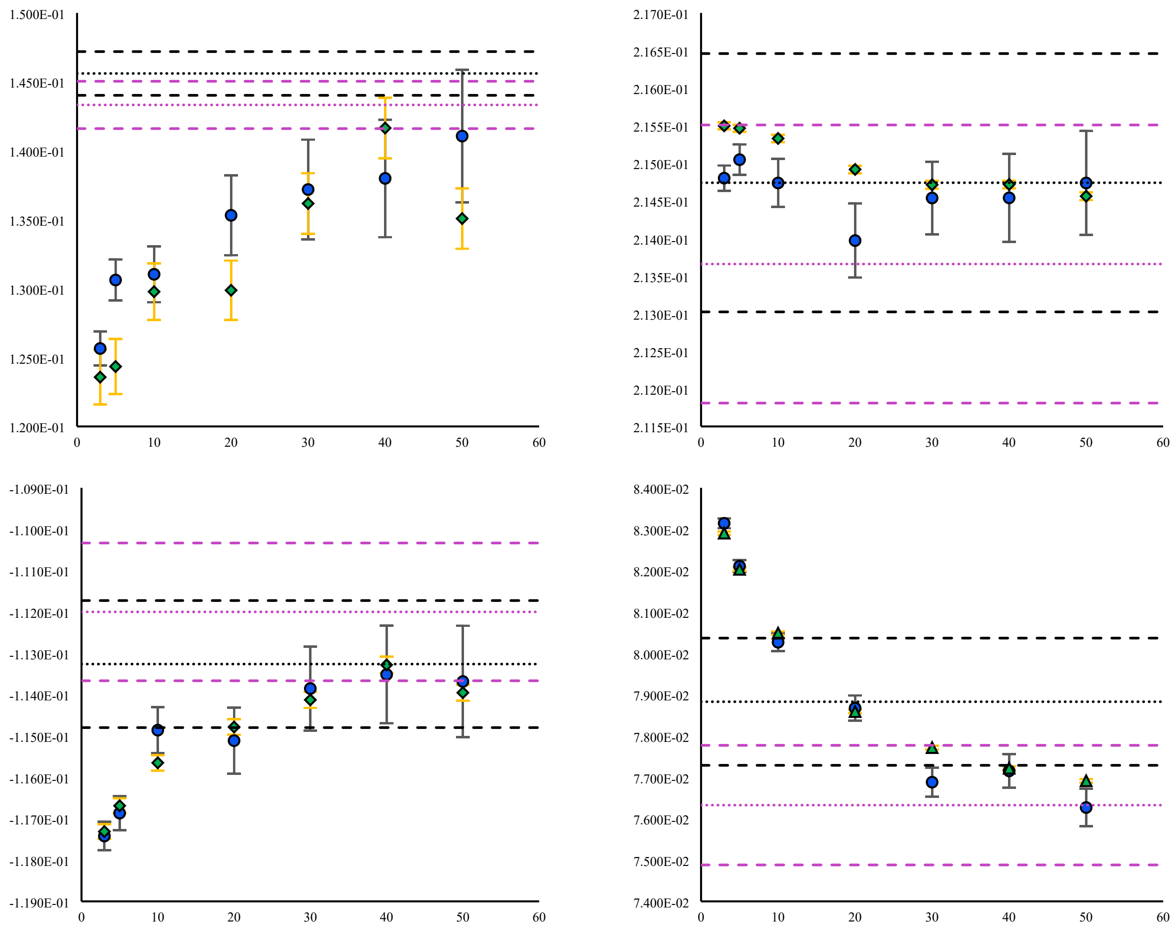

Figure 4. MPC-32 storage canister sensitivity coefficients by number of latent generations: ^{1}H (upper left), ^{235}U (upper right), ^{238}U (lower left), and ^{239}Pu (lower right). Blue circles are IFP-Shift, and green diamonds are CLUTCH. Purple dashes are Shift DPs and 1σ bands, and black dashes are KENO DPs and 1σ bands.

The plots for ^{238}U and ^{239}Pu (lower left and right, respectively) in Figure 4 show the same trends of overpredicting the magnitude of the sensitivity with low numbers of latent generations. The results improve as the number of latent generations increase. Beyond 10 latent generations for both nuclides the calculated sensitivity values begin to approach and move within the 1σ uncertainty bands for the DP sensitivities. However, unlike the values for ^{238}U, the CLUTCH sensitivities (green diamonds) for ^{239}Pu (lower right) drift beyond the lower KENO-DP 1σ uncertainty band (dashed black line) following 40 latent generations. There also appears to be a peak for the ^{238}U sensitivities (lower left) for both methods at 40 latent generations. For the ^{238}U IFP-Shift calculations (blue circles), there are statistically significant differences between 3–5, 5–10, and 3–50 latent generations, and for CLUTCH (green diamonds) all comparative differences, including 3–50 latent generations, are significant. For the ^{239}Pu IFP-Shift calculations, all successive differences, including 3–50 latent generations, are significant, except for 30–40. Finally for CLUTCH, all differences were significant, including 3–50 latent generations, except for 30–40 and 40–50 latent generations.

When directly comparing the TSUNAMI generated sensitivities with the DP sensitivities, ^{1}H is the nuclide that exhibits the largest changes. It takes a minimum of 30 latent generations for ^{1}H with IFP-Shift to come within acceptable differences from the DP-Shift values. ^{1}H for CLUTCH, as observed in Figure 4 (upper left), shows that a maximum sensitivity value is reached at 40 latent generations and then decreases at 50. This is also reflected in the direct comparisons with the DP value where only the differences at 40 latent generations meet the desired agreement identified in [2] (see Table II).

Table 2. Direct comparison of TSUNAMI generated and Direct Perturbation sensitivity coefficients for ^{1}H in MPC-32 storage canisters.

	Latent Gen.	Sensitivity	σ	DP Sen.	σ	Diff. %	Diff. σ	Δ
IFP-Shift	3	0.1257	1.227E-03	0.1433	0.0017	-12.33%	8.37	-0.0177
	5	0.1306	1.483E-03			-8.86%	5.60	-0.0127
	10	0.1310	2.022E-03			-8.57%	4.63	-0.0123
	20	0.1353	2.891E-03			-5.59%	2.38	-0.0080
	30	0.1372	3.623E-03			-4.28%	1.53	-0.0061
	40	0.1380	4.261E-03			-3.72%	1.16	-0.0053
	50	0.1411	4.810E-03			-1.58%	0.44	-0.0023
CLUTCH	3	0.1236	1.978E-03	0.1456	0.0016	-15.13%	8.69	-0.0220
	5	0.1243	2.002E-03			-14.60%	8.33	-0.0213
	10	0.1298	2.059E-03			-10.87%	6.09	-0.0158
	20	0.1299	2.152E-03			-10.80%	5.88	-0.0157
	30	0.1362	2.204E-03			-6.48%	3.47	-0.0094
	40	0.1416	2.204E-03			-2.72%	1.46	-0.0040
	50	0.1351	2.183E-03			-7.23%	3.90	-0.0105

Note: highlighted values are beyond the accepted difference criteria as outlined in [2].

4 CONCLUSIONS

The paper demonstrates the impact of increasing the latent generation parameter on sensitivity calculations with SCALE. The results for three different models—PMF-001-001S, LCT-008-006, and the MPC-32 storage canister—show how increasing the number of latent generations in TSUNAMI calculations with IFP-Shift, IFP-KENO, and CLTUCH affect generated sensitivity values when compared with the DP values obtained from a change of ±0.5% Δ*k*. Depending on the system, energy, and/or nuclide, altering the number of latent generations with the `cfp` parameter can significantly impact the generated sensitivity coefficients. Generally, as the number of latent generations increases, the accuracy of the generated sensitivity value compared with the DP values increases with notable exceptions.

Although the sensitivities generated with the IFP method appear to be generally more stable, the CLUTCH method has an advantage over serial IFP-KENO calculations in its parallel implementation. With the addition of the Shift Monte Carlo solver beginning in SCALE 6.3, IFP calculations can now be performed with the same parallel computing abilities as CLUTCH, thus allowing analysts a choice of parallelized methods when generating sensitivity values. Analysts must balance the calculational method along with the associated uncertainties that accompany specific sensitivity methods. Although the IFP generated sensitivity coefficients are mostly stable, there is a significant increase in the uncertainty in those calculated values compared to results with fewer latent generations. As the number of latent generations increases, the uncertainty also increases, which is most notably observed in systems with ^{1}H and ^{238}U or ^{239}Pu. Work continues in this area as additional parameters and calculational methods, such as Monte Carlo N-Particle and multigroup, are examined to provide analysts insights into how to successfully generate sensitivity coefficients to be used for confirmatory analyses and validation efforts.

5 ACKNOWLEDGMENTS

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