A Case Study in the Application of TSUNAMI-3D – Part 2, Continuous Energy
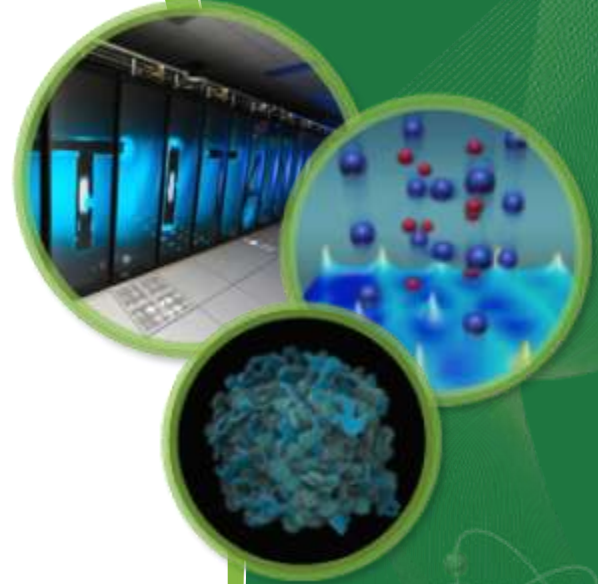
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Outline

1. Introduction

2. Code Description

3. Direct Perturbation Calculations

4. Experiment Description

5. Results

6. Conclusion

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Introduction

- TSUNAMI: sensitivity and uncertainty tool suite within SCALE

- SCALE 6.2 expanded the TSUNAMI capabilities to continuous energy (CE)

- Discuss the use of direct perturbation (DP) calculations

- Provide a case study to confirm accuracy of sensitivities generated by CE CLUTCH

- Companion paper for the MG results

- Models are executed using CE library based on ENDF/B-VII.1 in SCALE 6.2

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Code Description – CE TSUNAMI-3D CLUTCH

- CLUTCH (Contributon-Linked eigenvalue sensitivity/Uncertainty estimation via Tracklength importance Characterization): uses importance of events in a particle's lifetime, which is used to calculate eigenvalue sensitivity coefficients

- CLUTCH requires an F*(r) function
  - Average importance of a fission neutron generated at location r

- Unlike MG sensitivity calculations, the F*(r) mesh only needs to cover the fissionable regions

- User may need to simulate additional "inactive" histories to allow for sufficient F*(r) convergence

- Advantages:
  - significantly lower memory footprint than MG
  - parallel processing capabilities

- Disadvantages:
  - longer runtime than MG for most systems
  - requires more user experience compared to MG

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Direct Perturbation Calculations

- TSUNAMI sensitivity can be confirmed by using DP calculations

- DP sensitivity = reference sensitivity

- SDF (sensitivity data file) is created using the TSUNAMI-3D sequence

- Select important isotopes, elements, and/or materials of interest
  - include at least the primary fission and moderator species

- Perturbation selected to cause ±0.5% Δk change
  - perturbation large enough to yield accurate results and small enough to generate a linear response

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Direct Perturbation Calculations

- Uncertainty-weighted linear least squares fit of k_{eff} points used to determine the DP sensitivity
  - slope of the trend line is the sensitivity

- Desirable for the differences between TSUNAMI and DP sensitivities to be:
  - less than 5%
  - less than 0.01 in absolute sensitivity
  - less than 2 standard deviations using the combined uncertainties

- TSUNAMI sensitivities improved by increasing:
  - number of latent generations (generations between an event and the assessment of importance)
  - number of skipped generations
  - total number of active histories
  - resolution of the F*(r) mesh grid

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Description of HEU-MET-MIXED-017
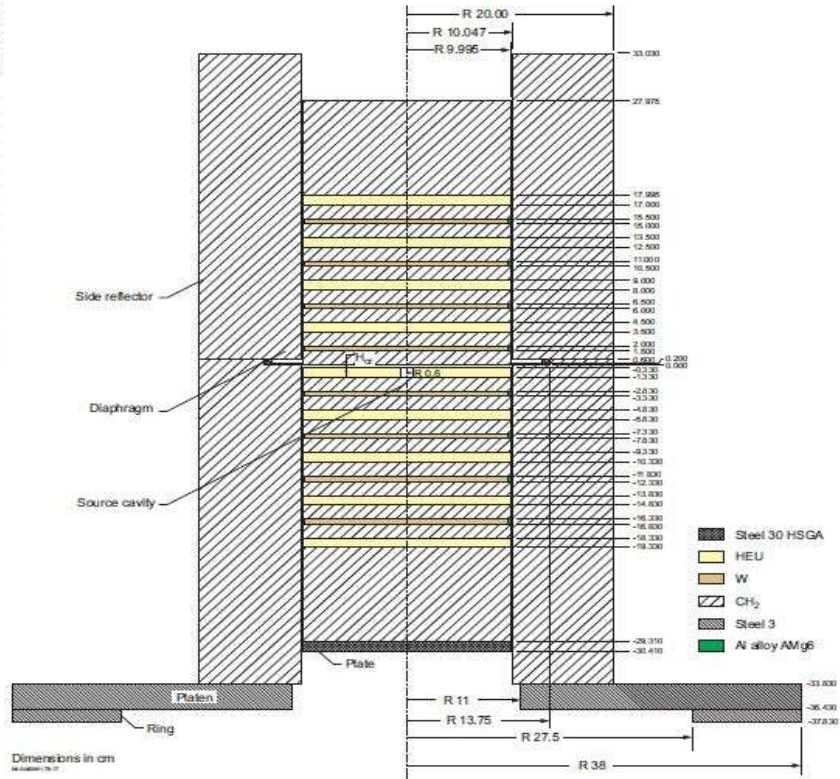
Configuration of the HMM-017 Model

- Model from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook

- 1 critical experiment

- Heterogeneous cylinder of alternating disks of HEU, polyethylene, and tungsten reflected by polyethylene

- Core is divided by a horizontal gap into 2 sections: a movable bottom part and a stationary top part

- Calculations used KENO V.a

Results – Sensitivity Comparisons for Base Model – Single Mixture

Isotope	ΔS (%)	ΔS (σ)	ΔS (abs)
C (refl)	1.61	0.69	0.0006
C (disk)	3.60	1.26	0.0009
H (disk)	1.56	0.27	0.0009
^{235}U	1.14	0.51	0.0031
^{182}W	0.09	0.05	0.0000
^{186}W	2.45	1.12	0.0006

- Mesh interval size: 1x1x1.33 cm
- *GEN*=3100, *NPG*=10k, *NSK*=100, *CFP*=5
- 13.5 hrs in serial

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Results – Sensitivity Comparisons for Refactored Model – Unique Mixtures

Isotope	ΔS (%)	ΔS (σ)	ΔS (abs)
C (refl)	0.79	0.53	0.0003
C (disks)	0.39	0.19	0.0001
H (disks)	6.79	1.19	0.0041
^{235}U (disk 1)	3.98	2.88	0.0005
^{235}U (disk 2)	1.69	1.21	0.0004
^{235}U (disk 3)	1.27	0.95	0.0005
^{235}U (disk 4)	1.66	1.28	0.0008
^{235}U (disk 5)	0.74	0.54	0.0003
^{235}U (disk 6)	2.86	2.19	0.0013
^{235}U (disk 7)	1.71	1.26	0.0006
^{235}U (disk 8)	1.42	1.05	0.0003
^{235}U (disk 9)	2.37	1.71	0.0003

- Mesh interval size: 1x1x1.33 cm

- *GEN*=3100, *NPG*=10k, *NSK*=100, *CFP*=5

- 16.6 hrs in serial

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Results - Axial profile of ^{235}U sensitivity by disk

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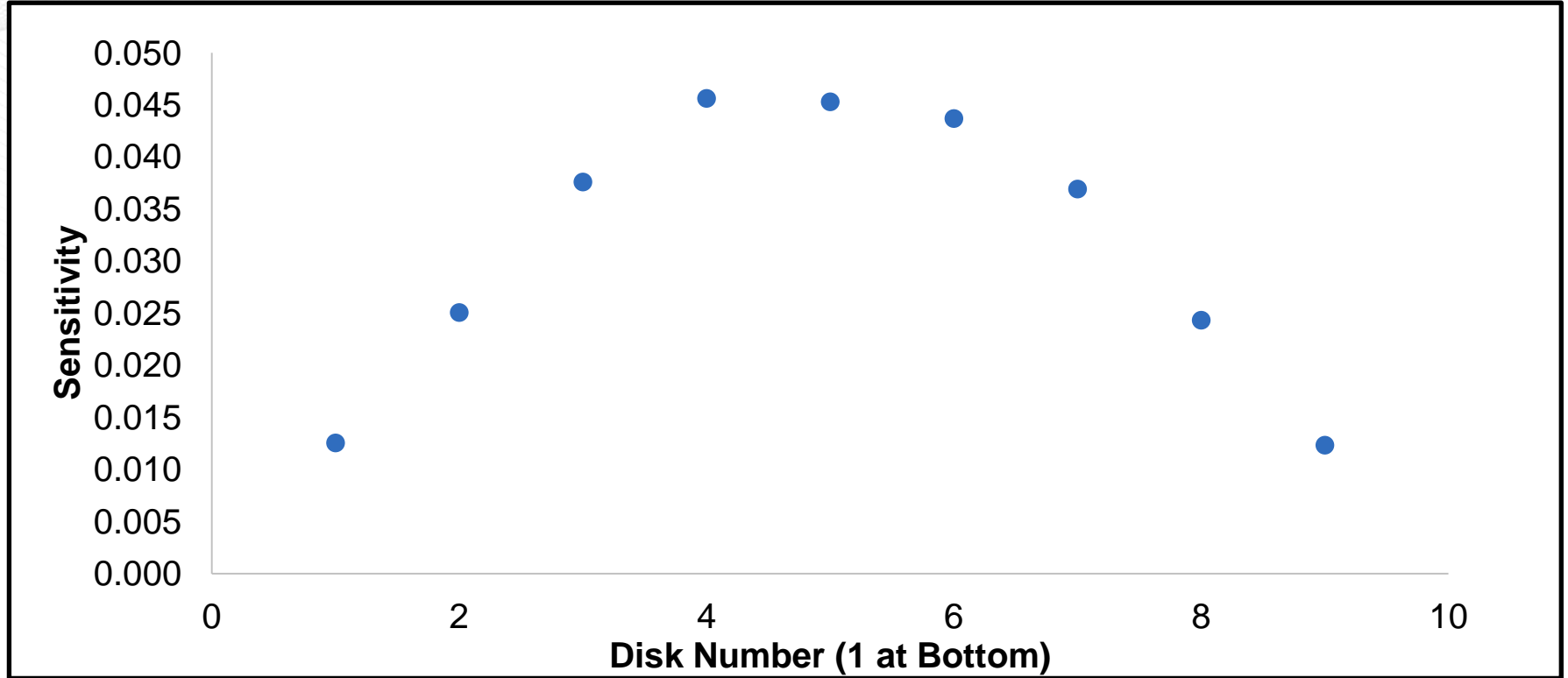
Results - TSUNAMI-3D and DP sensitivity comparisons for representative HMM-017-001 nuclides
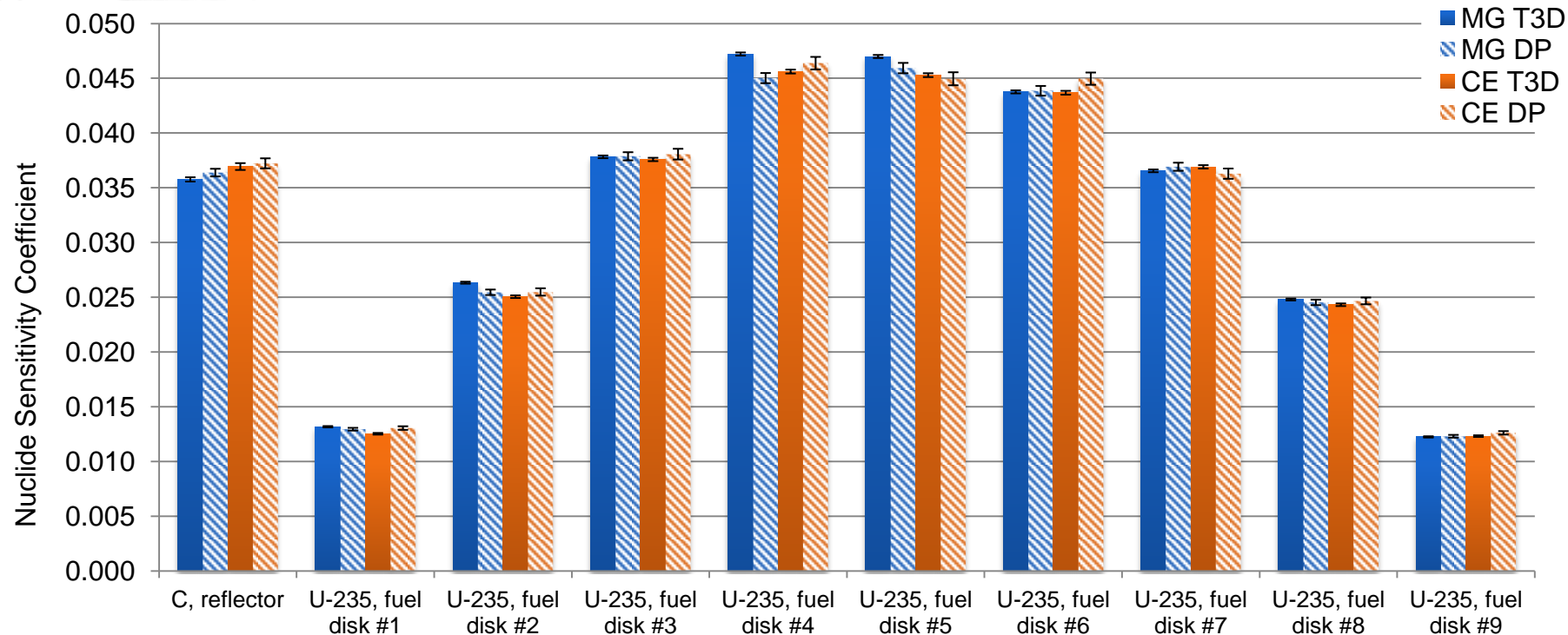
Conclusion

- CE CLUTCH sensitivities are accurate when compared to the DP sensitivities for HMM-017

- Overall, the sensitivity results reported by TSUNAMI for MG and CE CLUTCH are consistent for HMM-017

- **The use of DP calculations to confirm TSUNAMI sensitivities is an essential step in the process of SDF generation**

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Acknowledgement

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