

Sensitivity/Uncertainty Comparison Study: Oak Ridge National Laboratory Results

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Overview

- Various methods and sensitivity/uncertainty tools have been developed over the years to assist in determining upper subcritical limits (USLs)
- Task – compare calculated USLs from various methods on a small set of benchmark problems.
- Benchmark experiments selected (applications):
 - HEU-MET-FAST-013-001
 - HEU-SOL-THERM-001-008
 - PU-MET-FAST-022-001
 - PU-SOL-THERM-001-001



ORNL Results

- Tools for Sensitivity Uncertainty Analysis Methodology Implementation (TSUNAMI) from SCALE 6.2.3 code suite
- Computational models/sensitivity data files (SDFs) are from VALID
- TSUNAMI-IP used to compare SDFs between selected benchmarks and available benchmark experiments to calculate correlation coefficient c_k
- TSUNAMI-IP also used to generate inputs for the Upper Subcritical Limit Statistical Software (USLSTATS) trending analysis
- ENDF/B-VII.1 cross sections, 252 group covariance library

ORNL Results (continued)

- USLSTATS – used c_k as a trending parameter to determine bias and bias uncertainty (no additional margins of safety)
 - Evaluated with c_k thresholds of 0.8, 0.9, and 0.95
 - $USL = 1.0 + \text{bias} - \text{bias uncertainty}$
 - No credit for positive biases
 - No additional safety margins
- TSUNAMI-IP run with and without option for correction/patches to the covariance data (when cross-section-covariance data are too large or not available in the covariance library)



ORNL Results (continued)

- Following slides will go through each case
 - Each experimental and calculated value
 - Number of applicable experiments and the USL determined for each c_k threshold (0.8, 0.9, 0.95)
 - Figure (USLSTATS plot) of the biased k_{eff} 's
 - Illustrates effect of changing the pool of applicable experiments

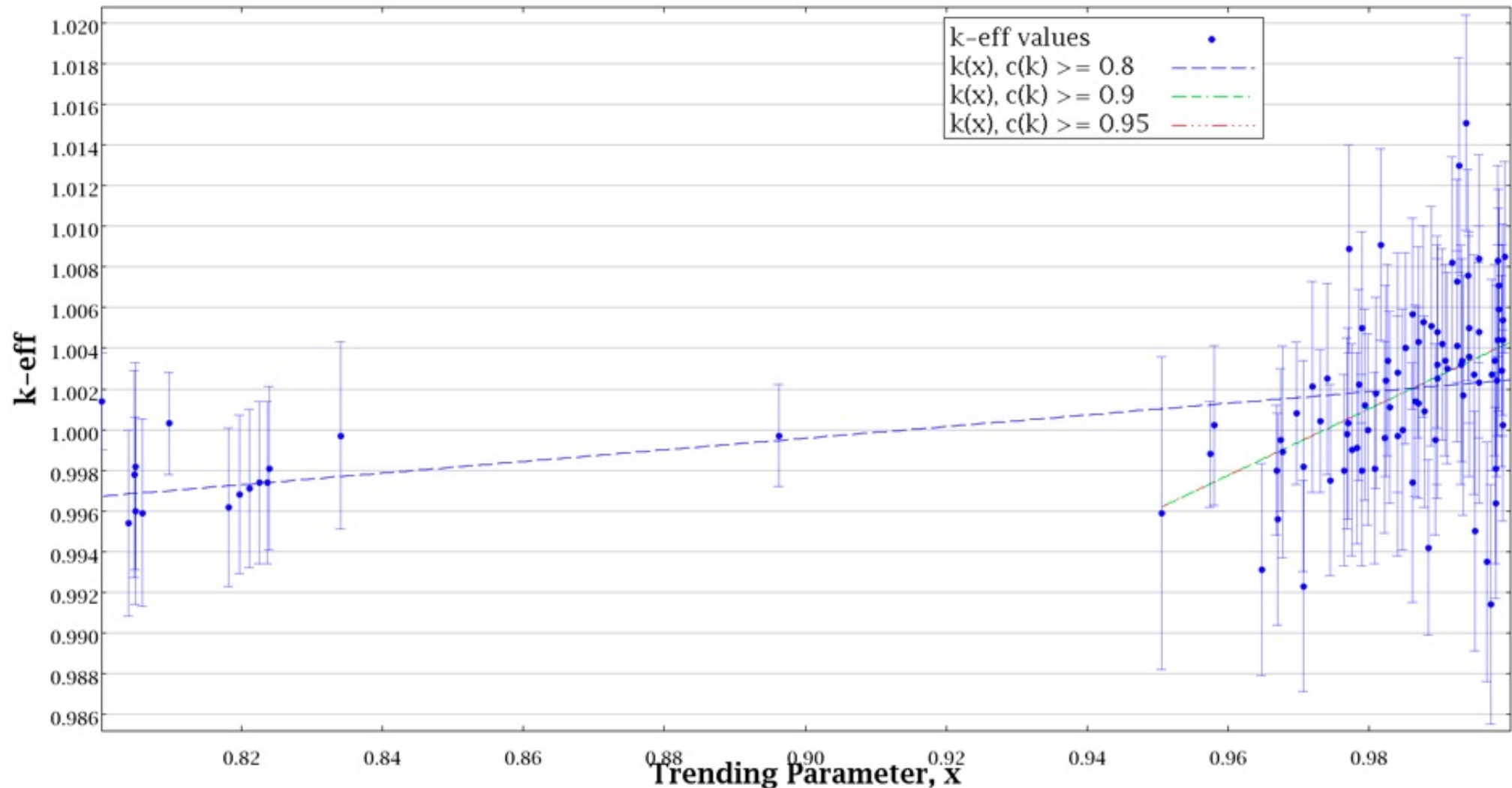
ORNL Results – PU-SOL-THERM-001-001

- Description – critical assembly consisting of sphere of plutonium nitrate solution (73 g/L Pu with acid molarity of 0.2M nitrate)
 - Experimental: 1.0000 ± 0.0050
 - SCALE 6.2.3 : 1.0039 ± 0.0001

Minimum C_k	Number of Experiments	Bias	Bias Uncertainty	USL
0.8	100	0.0025	0.0105	0.9895
0.9	85	0.0043	0.0108	0.9892
0.95	85	0.0043	0.0108	0.9892

ORNL Results – PU-SOL-THERM-001-001 (continued)

- Biased k_{eff} (from USLSTATS)



ORNL Results – PU-SOL-THERM-001-001 (continued)

- Lots of applicable experiments make for similar trends and very similar USLs
- No difference between c_k threshold value of 0.9 and 0.95 – same number of experiments
- Including additional, less applicable experiments (c_k threshold value of 0.8), changes the slope and the resultant USL (negligible in this case)
- Positive bias is well-predicted
 - No credit for positive bias
 - If credited, resultant USL would be 0.9920 (c_k of 0.8) or 0.9935 (c_k of 0.9 or 0.95)

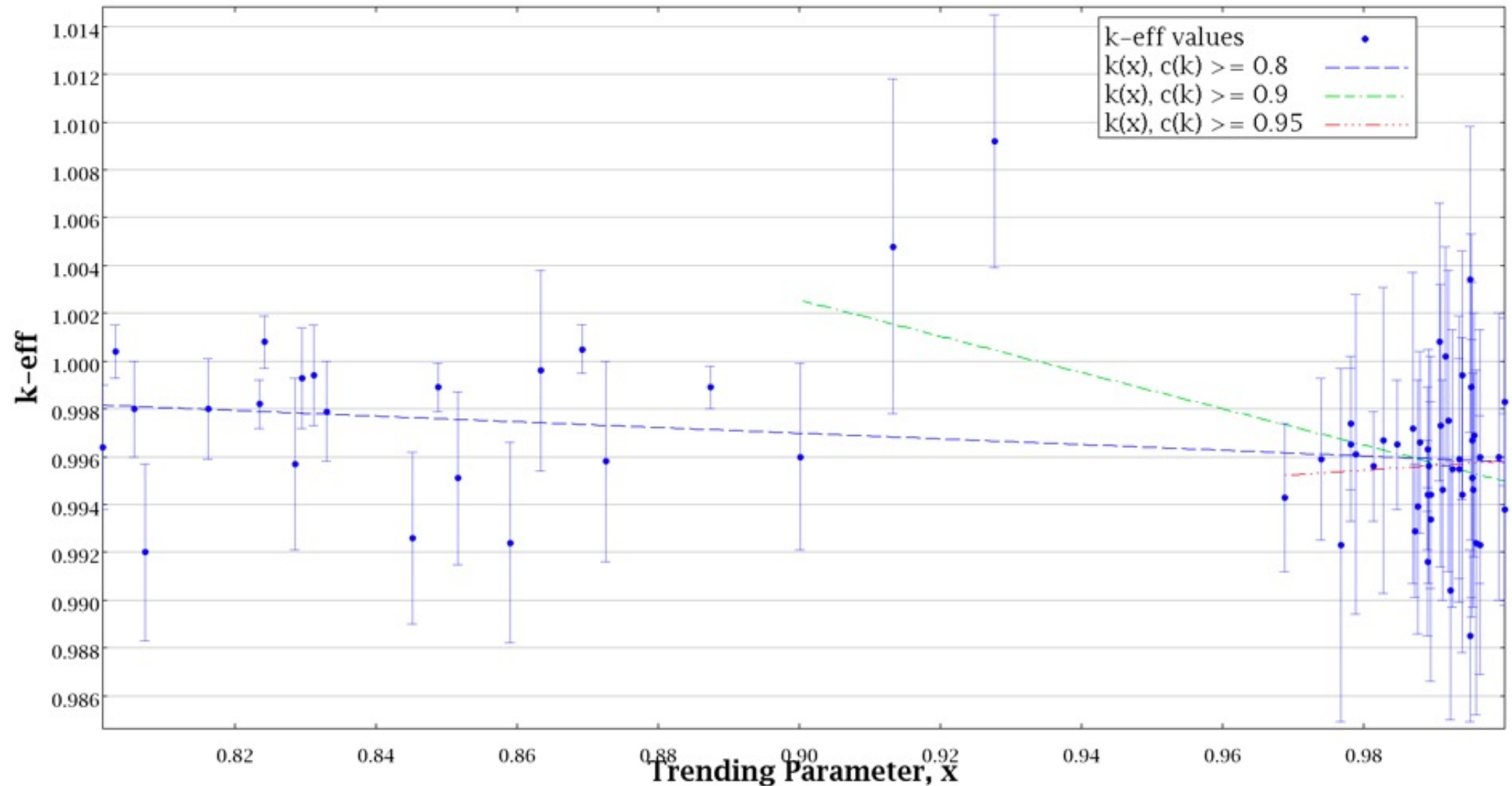
ORNL Results – HEU-SOL-THERM-001-008

- Description – critical assembly consists of cylinder of highly enriched uranyl nitrate solution (146 g/L U with acid molarity of 0.3M nitrate)
 - Experimental: 0.9998 ± 0.0038
 - SCALE 6.2.3 : 0.9959 ± 0.0001

Minimum C_k	Number of Experiments	Bias	Bias Uncertainty	USL
0.8	65	-0.0042	0.0095	0.9863
0.9	46	-0.0050	0.0104	0.9846
0.95	43	-0.0042	0.0101	0.9857

ORNL Results – HEU-SOL-THERM-001-008 (continued)

- Biased k_{eff} (from USLSTATS)



ORNL Results – HEU-SOL-THERM-001-008 (continued)

- Again we see the cluster of points above the c_k threshold value of 0.95
- Again slope changes with different selection of experiments – trend flips with c_k threshold value of 0.95
 - Same bias as with a c_k threshold value of 0.8, but different uncertainty, so slightly different USL
 - Demonstrates the potential hazard of declaring general c_k cutoffs
- Very similar USLs

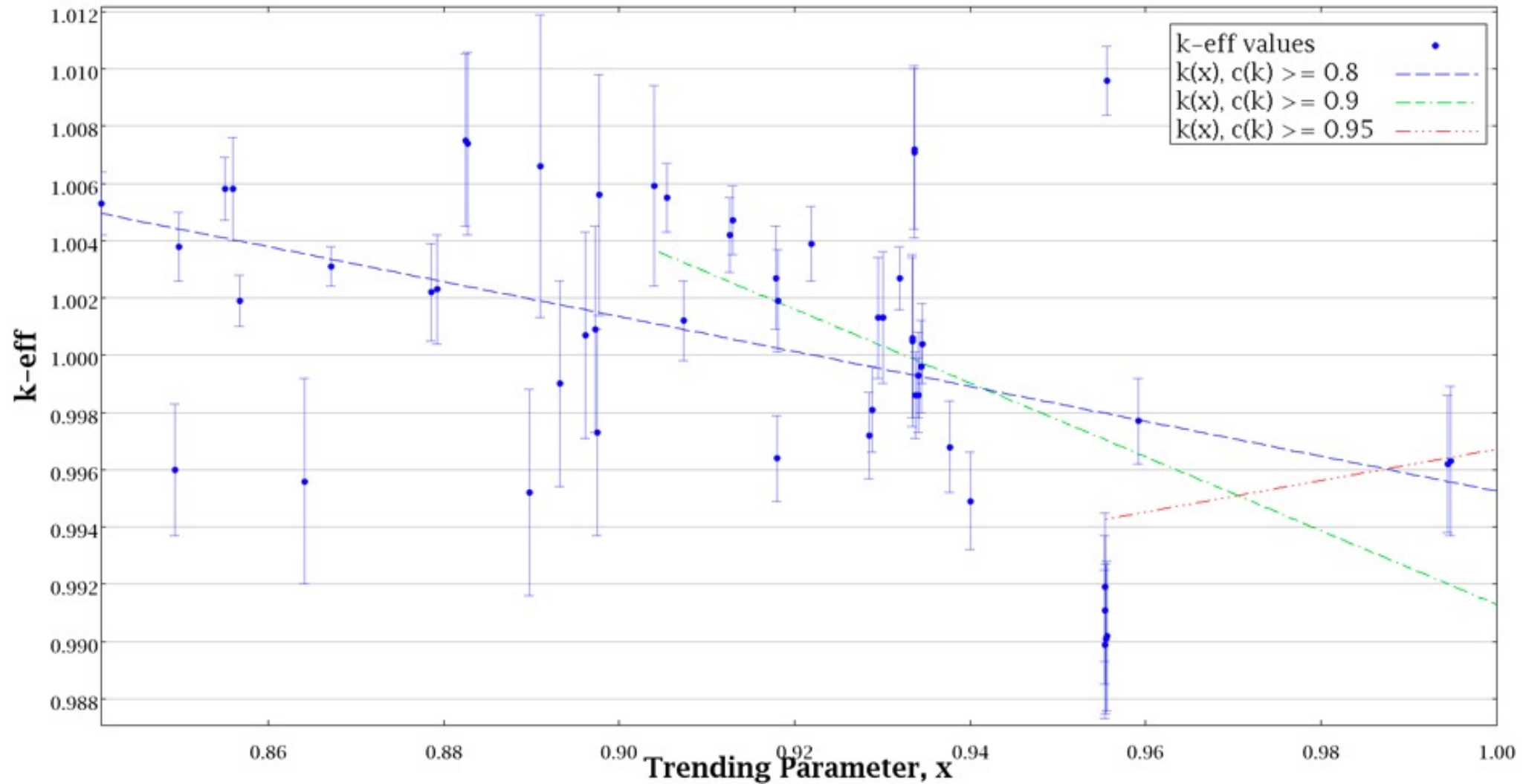
ORNL Results – HEU-MET-FAST-013-001

- Description – critical assembly is a steel reflected sphere of highly enriched uranium metal
 - Experimental: 0.9990 ± 0.0015
 - SCALE 6.2.3 : 0.9973 ± 0.0001

Minimum C_k	Number of Experiments	Bias	Bias Uncertainty	USL
0.8	53	-0.0047	0.0090	0.9863
0.9	34	-0.0087	0.0094	0.9819
0.95	9	-0.0032	0.0173	0.9795

ORNL Results – HEU-MET-FAST-013-001 (continued)

- Biased k_{eff} (from USLSTATS)





ORNL Results – HEU-MET-FAST-013-001 (continued)

- Values are more spread out, not so many grouped on the high end
- Again, slope changes with different c_k threshold value
 - c_k threshold value of 0.95 has different trend
 - Only 9 experiments have a c_k greater than 0.95 (USLSTATS requires a minimum of 25 for its normality test)
 - Bias is smaller but the resultant USL is lower because of its higher bias uncertainty (almost double)
- Using the option for correction/patches to the covariance data yielded slightly different results

ORNL Results – HEU-MET-FAST-013-001 (continued)

- 6 fewer experiments at c_k threshold values of 0.8 and 0.9
 - Vanadium reflector in all 6 experiments (not in HMF-013-001)
 - V-51 scattering reaction is a major contributor to the uncertainty
 - Without the correction/patch, c_k value is 0.94 for all 6 experiments
 - With the correction/patch, c_k value is lower than 0.7, with most being less than 0.5

Min. c_k	No. of Exp.	Bias	Bias Uncert.	USL
With correction/patches option				
0.8	53	-0.0047	0.0090	0.9863
0.9	34	-0.0087	0.0094	0.9819
Without correction/patches option				
0.8	59	-0.0035	0.0090	0.9875
0.9	40	-0.0078	0.0094	0.9828

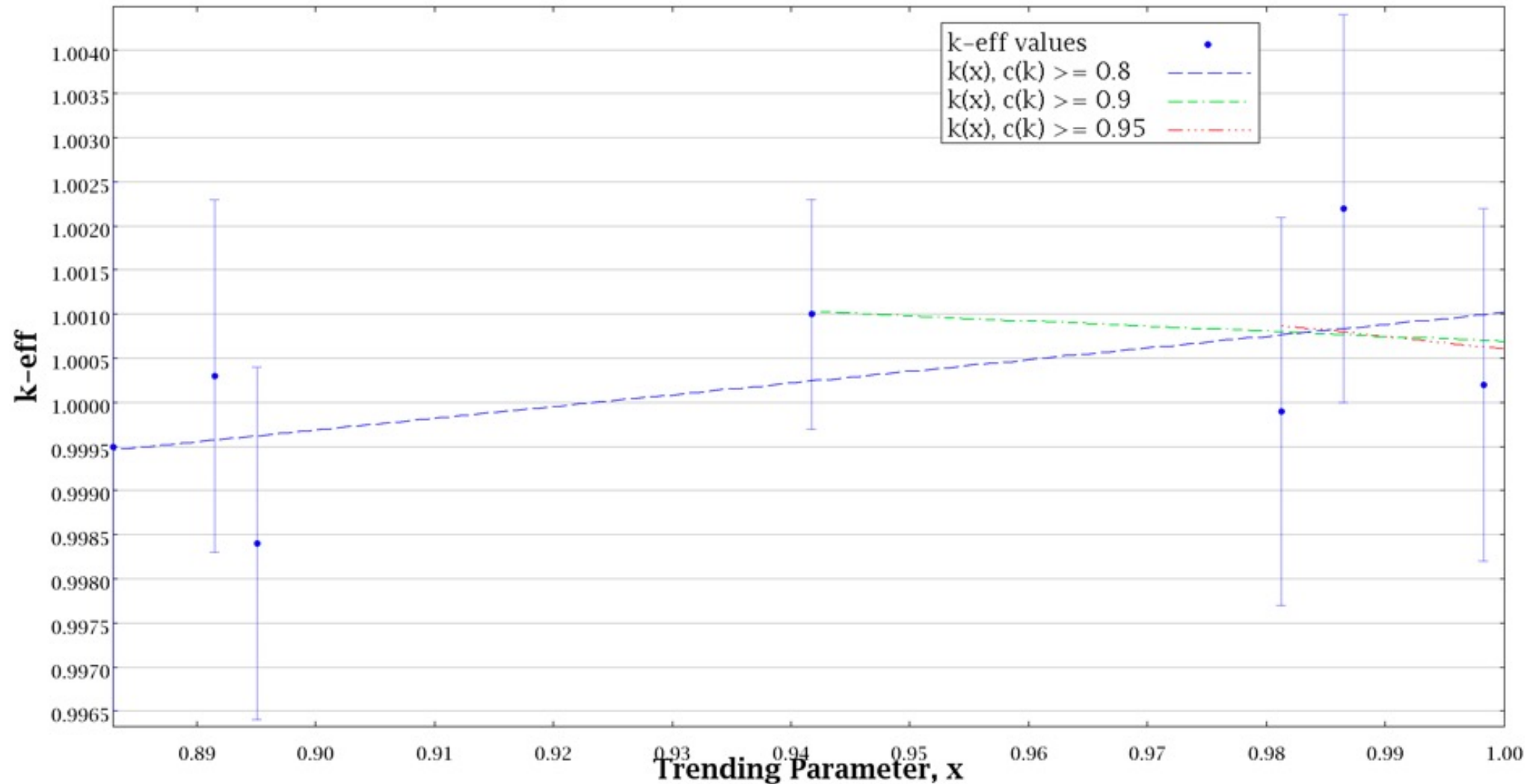
ORNL Results – PU-MET-FAST-022-001

- Description – critical assembly is a bare plutonium metal sphere with a small central cavity
 - Experimental: 1.0000 ± 0.0023
 - SCALE 6.2.3 : 0.9986 ± 0.0001

Minimum C_k	Number of Experiments	Bias	Bias Uncertainty	USL
0.8	7	0.0010	0.0057	0.9943
0.9	4	0.0006	0.0084	0.9916
0.95	3	0.0006	0.0258	0.9742

ORNL Results – PU-MET-FAST-022-001 (continued)

- Biased k_{eff} (from USLSTATS)





ORNL Results – PU-MET-FAST-022-001 (continued)

- Less than the minimum of 25 for the normality test
 - USLSTATS output – ‘satisfied a normal distribution test’ but flagged as ‘unreliable’
- No credit for positive bias
- How many applicable experiments are really needed?



Summary Observations

- Overall, method works well
 - Within a few tenths of a percent on a bias-corrected basis in all cases
- Generally, the larger pools (number of experiments) of applicable experiments resulted here in smaller bias uncertainties
 - Larger pools are for lower c_k thresholds
 - No similar trend in magnitude of bias

Summary Observations (continued)

- The impact of different c_k thresholds depends on the system....has potential to be significant
 - Important to look at the spread in the data
- None of the c_k thresholds used here were low enough to give clearly wrong results
 - May be that it takes much larger number of bad experiments to cause a negative effect
 - May also depend on the spread of the calculated k_{eff} 's
 - Evidenced by switch in slopes



Future Work

- Compare results with others involved in the NCSP task
 - Los Alamos National Laboratory (LANL)
 - Institute for Radiological Protection and Nuclear Safety (IRSN)
- Determine
 - What we each do well
 - What we each don't do so well
 - Areas we can improve

Questions?

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