Validation of Spent Nuclear Fuel Output by Cyclus, a Fuel Cycle Simulator Code

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Outline

Nuclear Waste Repository Model

Long Term Goal

Run simulations to determine how varying certain variables in the nuclear fuel cycle impacts the mass loading of a nuclear waste repository for the U.S. nuclear fuel cycle.

Variables

- used fuel allocation strategies
- waste package material properties
- repository parameters
- presence of interim facilities

Cyclus

`Cyclus` is an agent-based nuclear fuel cycle simulator with a modular, extendable framework.

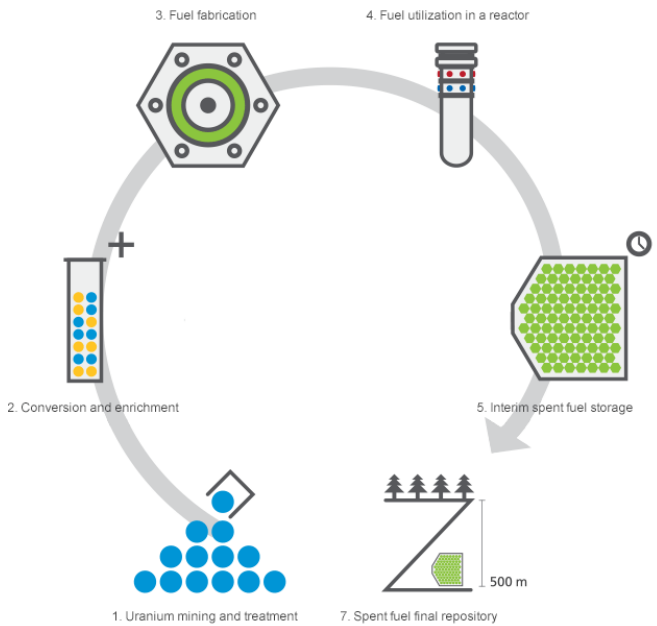


Figure 1: Once Through Nuclear Fuel Cycle [1]

Motivation for conducting the Validation

The main constraint for loading of a waste repository is the **thermal constraint** set by the material properties of the repository.

Waste package thermal evolution depends on the **decay heat contribution from each isotope** in the spent fuel.

Therefore, to **correctly simulate loading of a nuclear waste repository based on thermal constraints** in Cyclus, the simulation must first give isotopic compositions and spent fuel masses that **closely replicate reality**.

Outline

Cyclus Simulation of historic U.S. nuclear fuel cycle

Reactor deployment data obtained from the Power Reactor Information System (PRIS) database [4] for the 112 commercial nuclear reactors that have operated since 1968 was used to create a CYCLUS **simulation of the U.S. nuclear fuel cycle**.

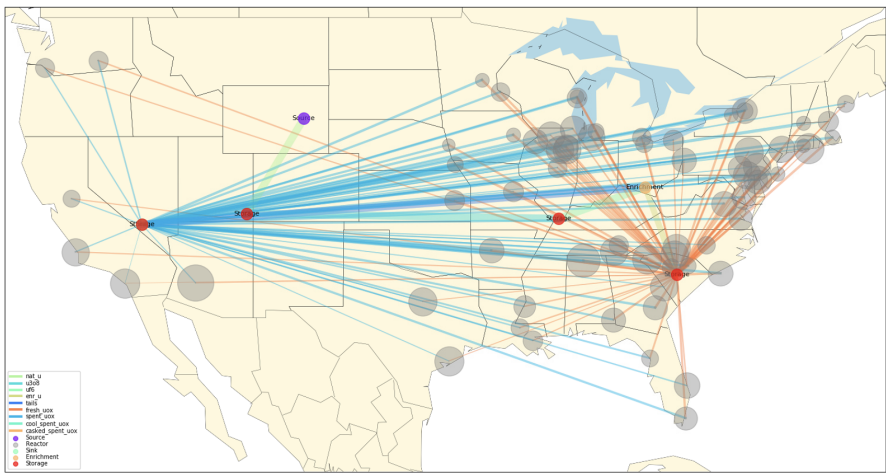


Figure 2: Cycmap of the historic Cyclus U.S nuclear fuel cycle simulation [3]

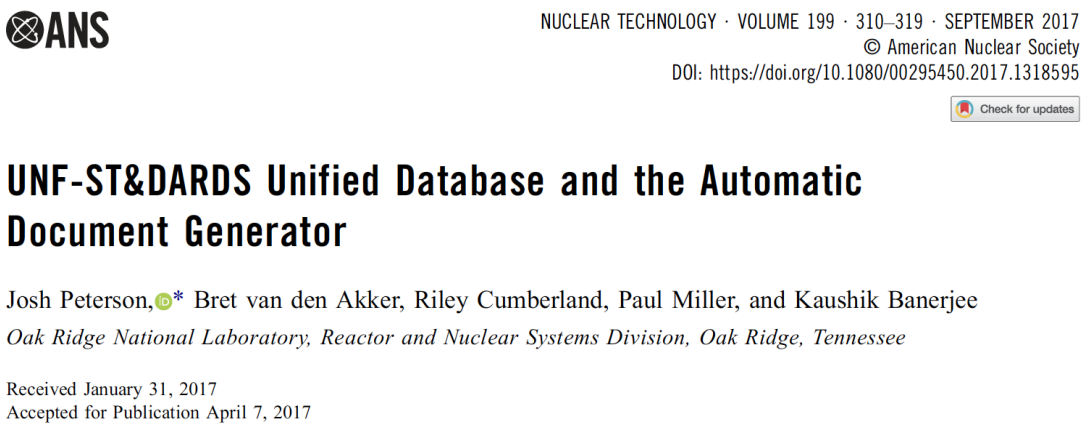
Assumptions

- constant refueling time
- constant reactor cycle time
- single spent fuel depletion composition

Comparison of Cyclus Simulation against Unified Database

The total spent fuel mass and specific isotopic compositions from the CYCLUS simulation and Unified Database were **compared**.

Unified Database contains **commercial SNF information** from 1968 through 2013 such as discharged fuel assembly data per reactor, specific isotopic concentrations and decay heat for each assembly along with its discharge date [4].



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UNF-ST&DARDS Unified Database and the Automatic Document Generator

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Figure 3: UNF-ST&DARDS Unified Database and the Automatic Document Generator Journal Article

Outline

Cyclus vs. Unified Database: Total Spent Fuel Mass

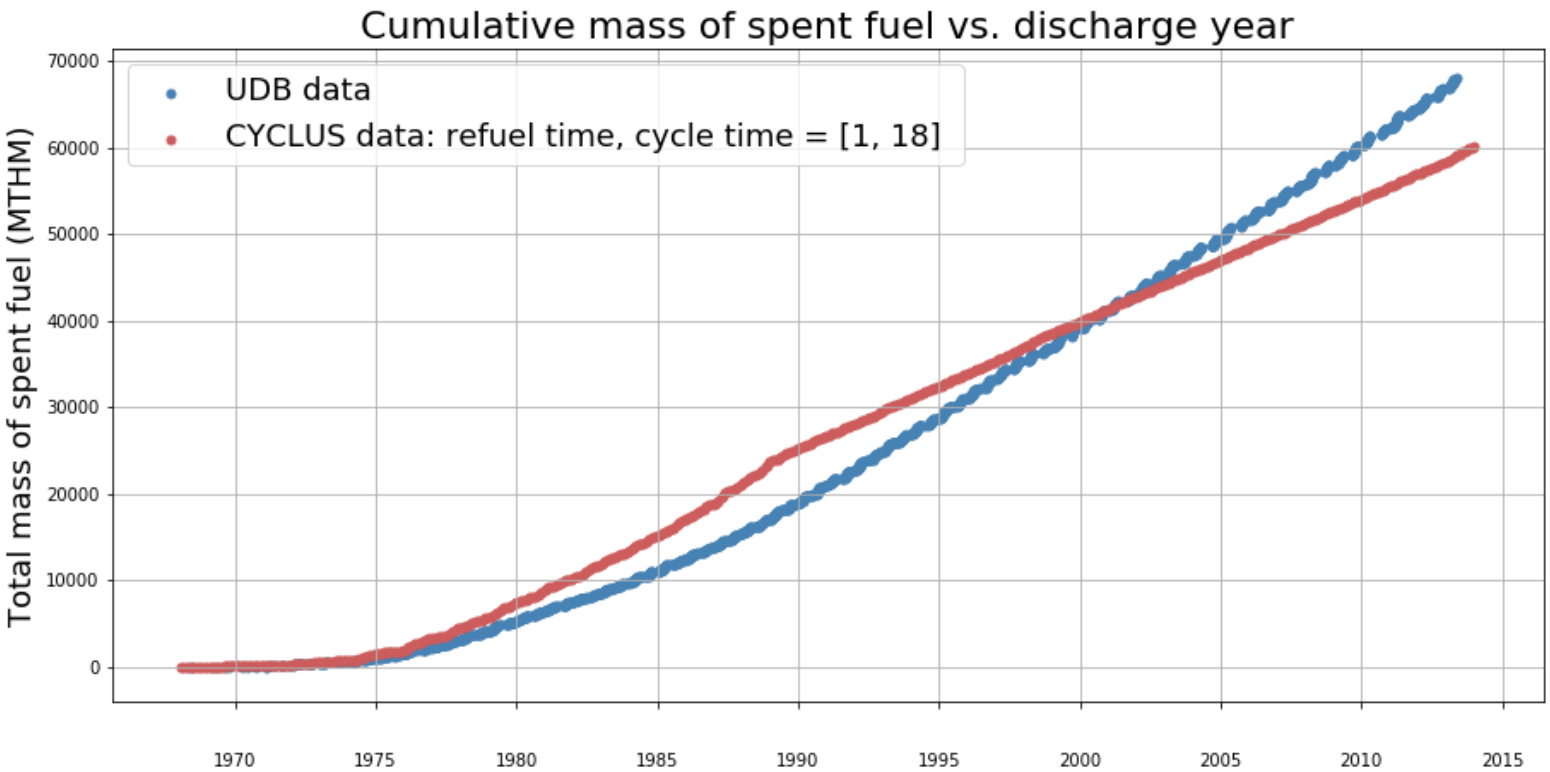

Figure 4: The cumulative spent fuel mass against discharge time for Cyclus and Unified Database data from 1968 through 2013.

Varying Refueling and Cycle durations in Cyclus Simulation

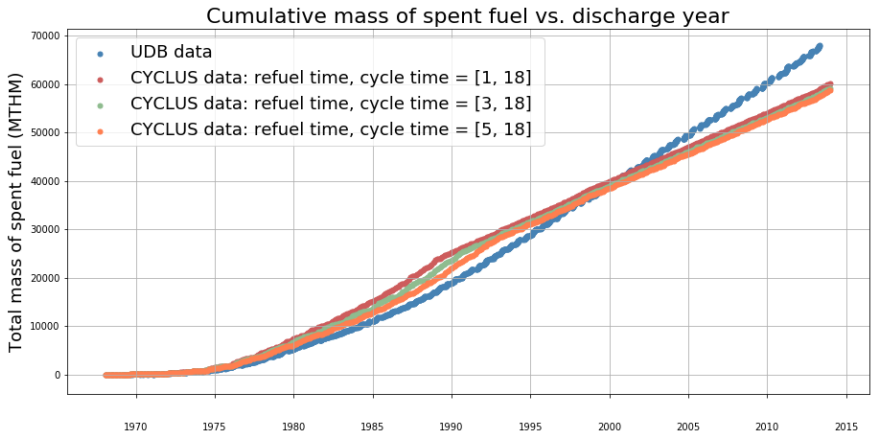

Figure 5: The cumulative spent fuel mass against discharge time for Cyclus and Unified Database data from 1968 through 2013 for varying **refueling and cycle durations**.

Cyclus vs. Unified Database: Major Isotopic Composition

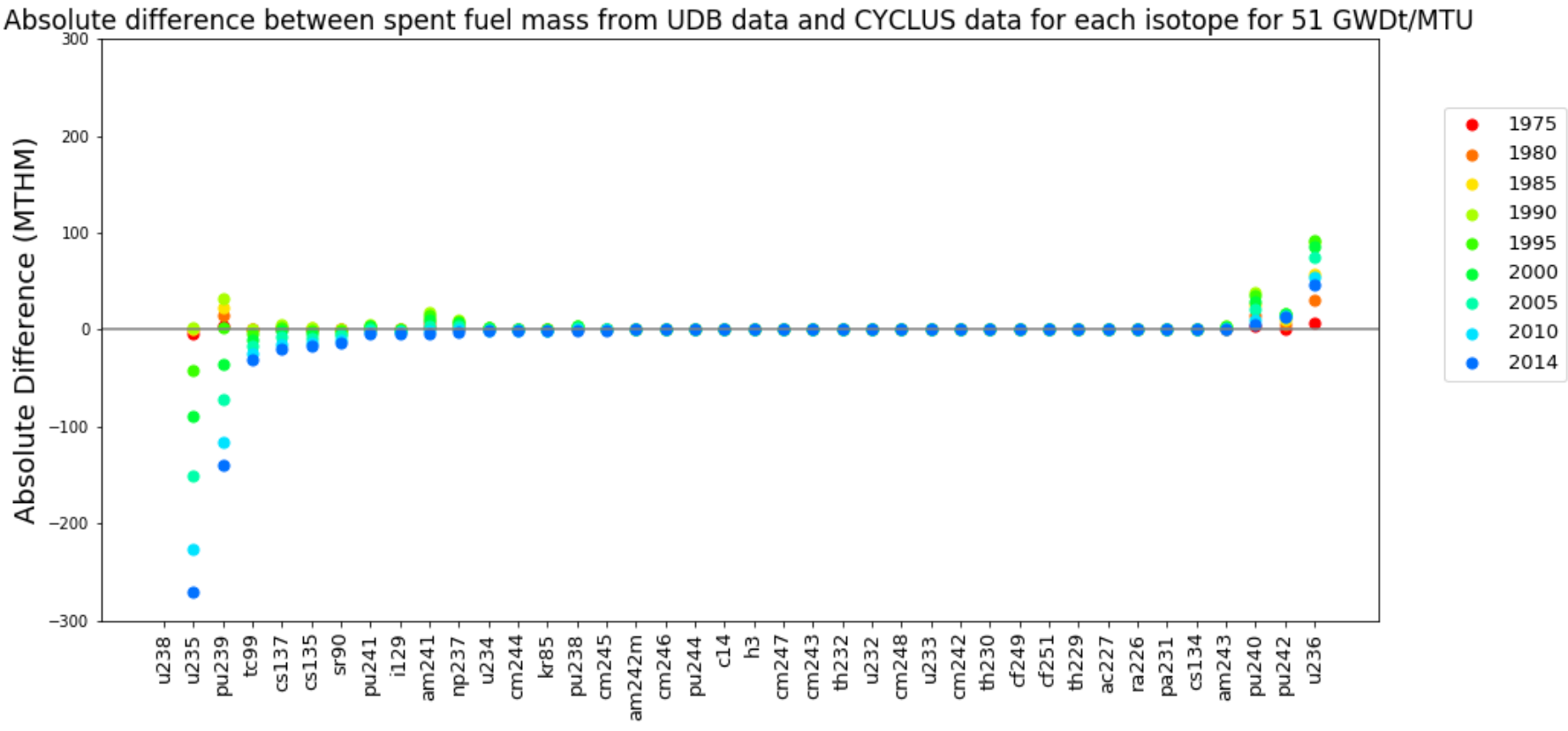

Figure 6: The absolute difference between cumulative spent fuel mass calculated by Unified Database and CYCLUS for each isotope. Spent fuel burnup of 51 GWD/MTU is used in the CYCLUS simulation. Positive difference indicates CYCLUS mass estimate is larger.

Cyclus vs. Unified Database: Major Isotopic Composition

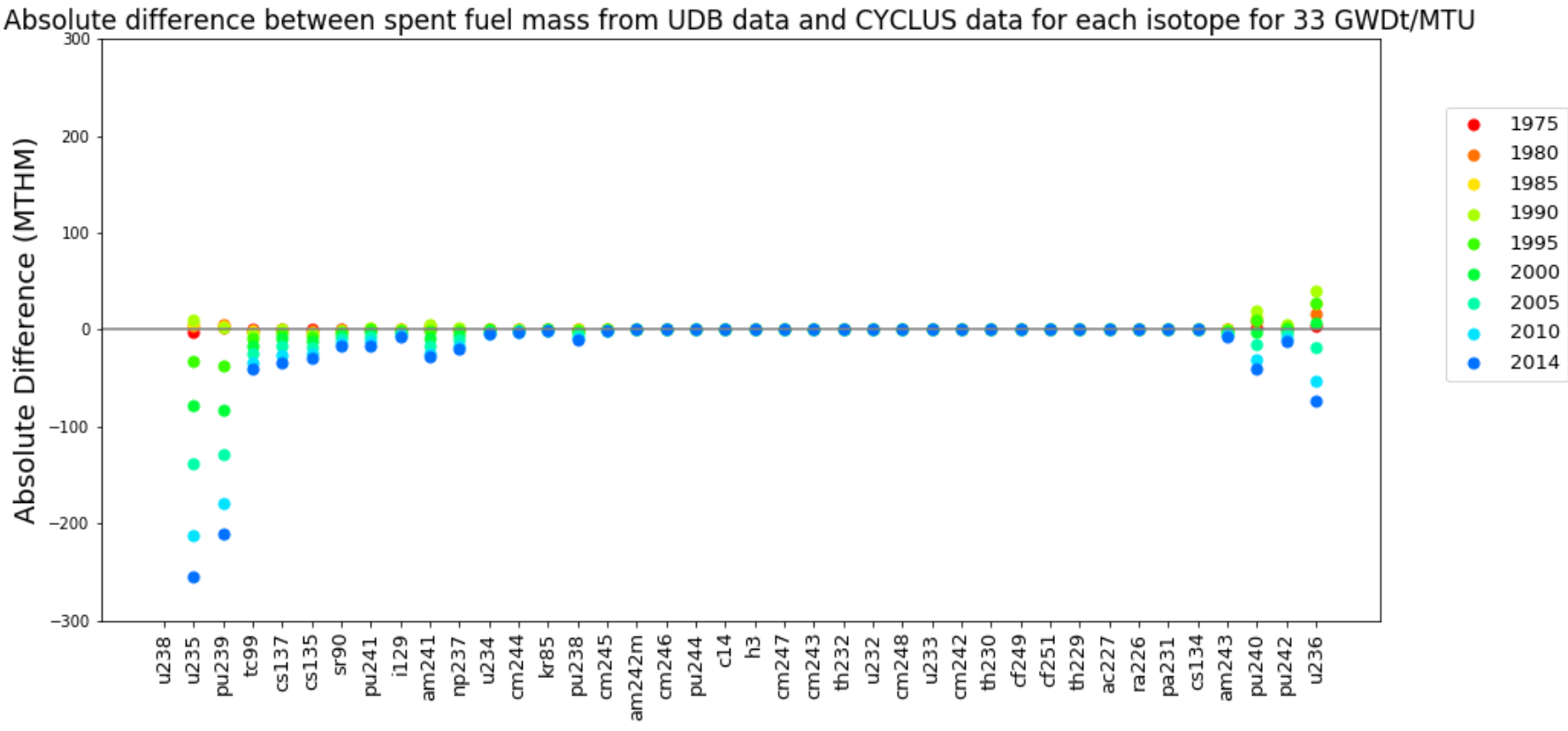

Figure 7: The absolute difference between cumulative spent fuel mass calculated by Unified Database and CYCLUS for each isotope. Spent fuel burnup of 33 GWD/MTU is used in the CYCLUS simulation. Positive difference indicates CYCLUS mass estimate is larger.

Burn up of Spent Nuclear Fuel

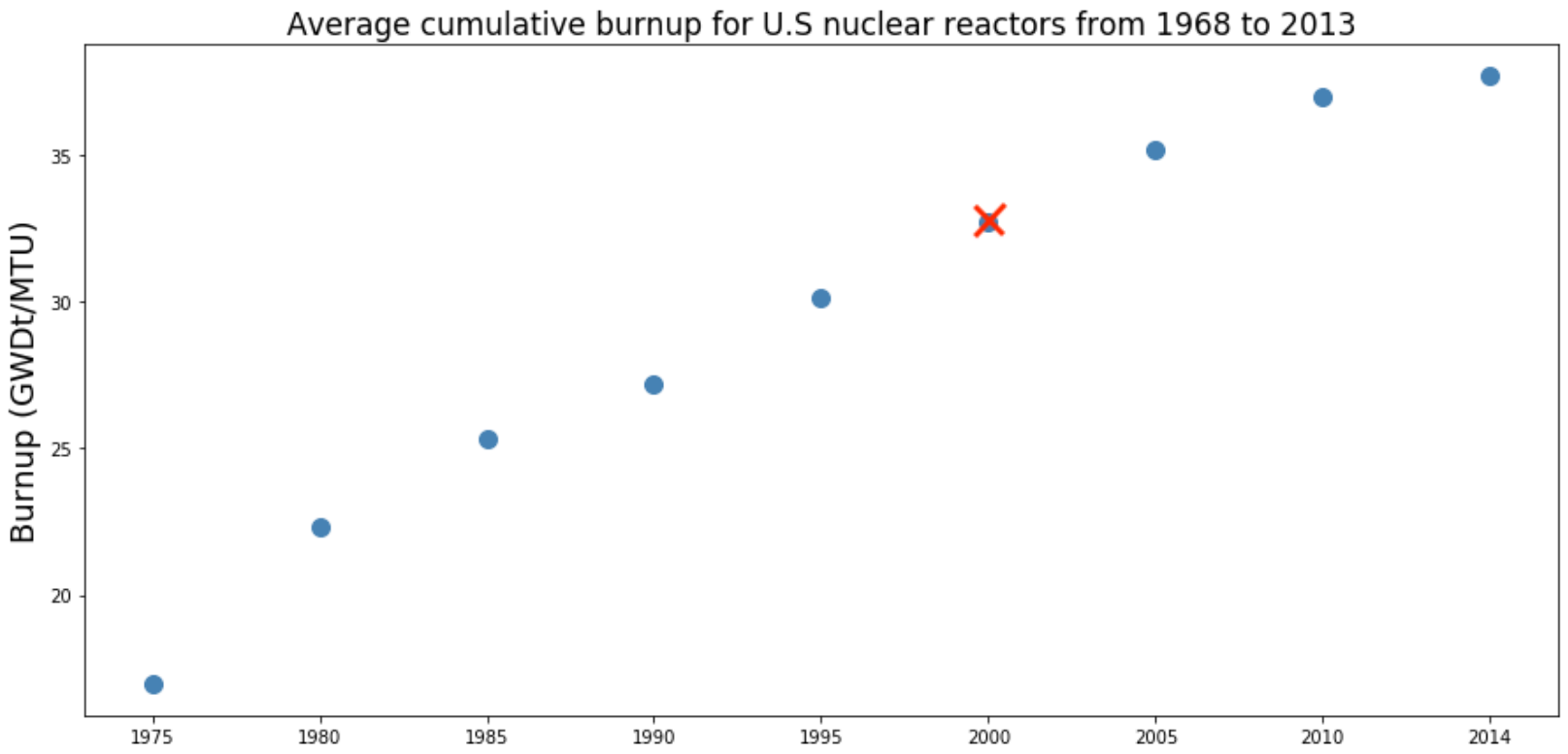

Figure 8: The average cumulative burnup for U.S. nuclear reactors from 1968 to 2013 [2].

Cyclus vs. Unified Database: Major Isotopic Composition

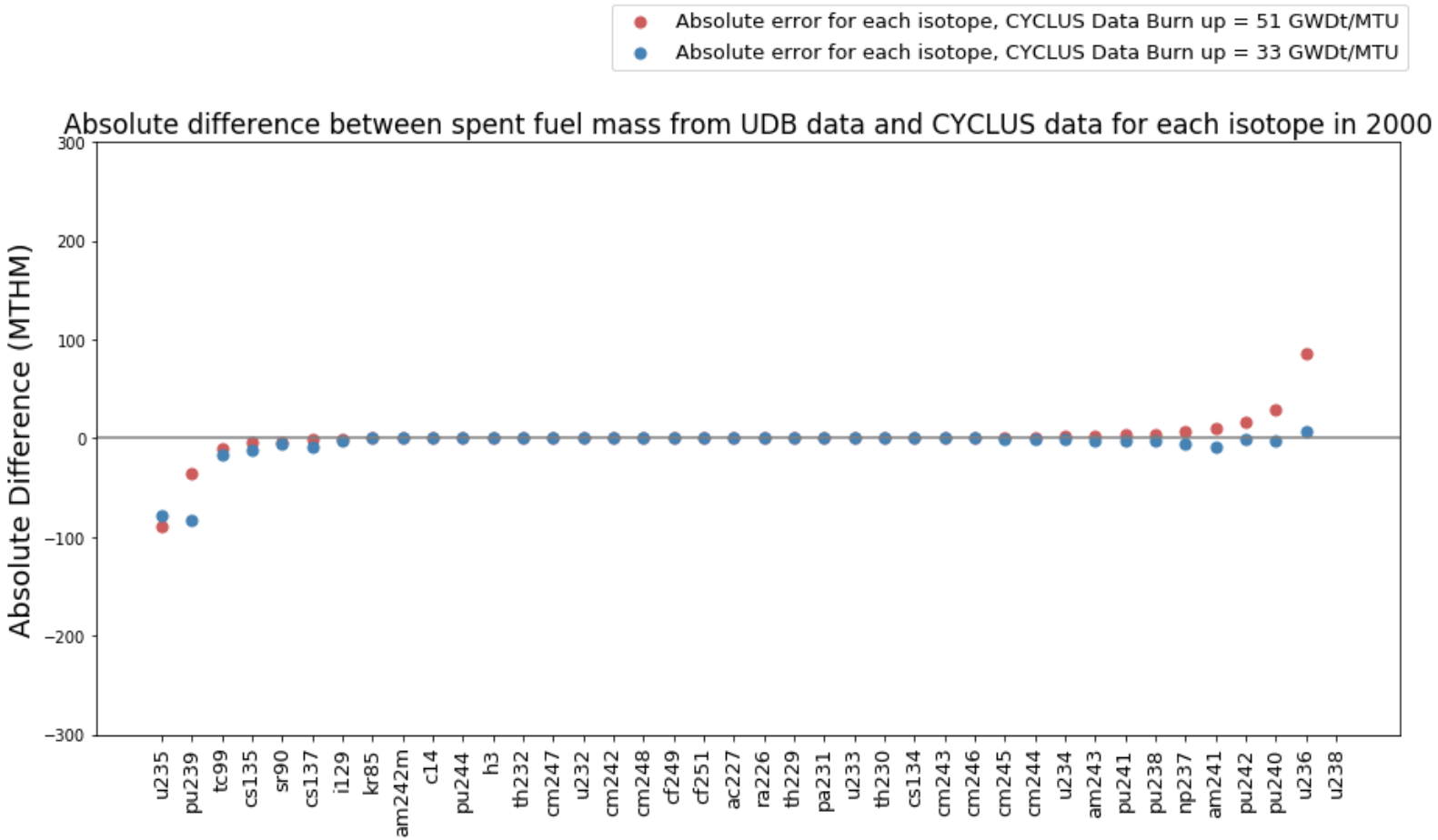

Figure 9: The absolute difference between cumulative spent fuel mass calculated by Unified Database and CYCLUS for each isotope at year 2000. Positive difference indicates CYCLUS mass estimate is larger.

Cyclus vs. Unified Database: Major Isotopic Composition

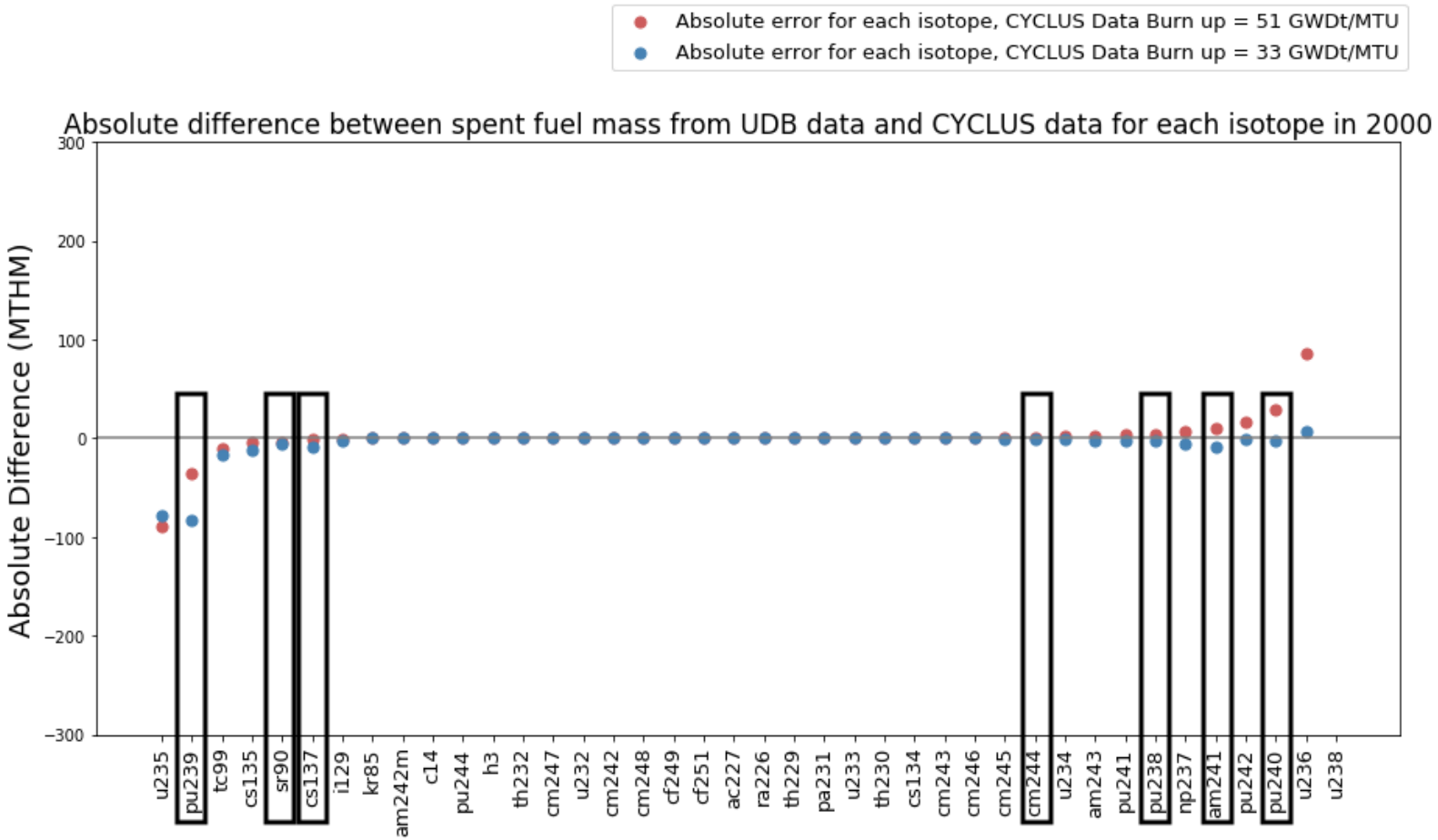

Figure 10: The absolute difference between cumulative spent fuel mass calculated by Unified Database and CYCLUS for each isotope at year 2000. The boxed isotopes are the major decay heat contributors.

Outline

Conclusion

These results demonstrate that the spent fuel mass calculated by the Cyclus simulation for the US nuclear fuel cycle follow **similar trends** as the real world metrics. However, there are significant mass differences in the important isotopes that contribute to decay heat.

Deviations from the real world metric can be explained by issues with the reactor facility in the CYCLUS model:

- only accepting integer month values for cycle and refueling durations
- single spent fuel recipe

Future Work

To more accurately model isotopic concentrations in the CYCLUS simulation, these capabilities could be implemented in CYCLUS:

- Reactor facility that is tied to a database of varying spent fuel recipes based on burnup + Toolkit that gives the functionality of varying cycle time and refuel duration values
- Reactor facility that is tied to the Unified database to give different spent fuel recipes based on the burnup of a specific spent fuel bundle

Acknowledgement

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UNF-ST&DARDS Unified Database and the Automatic Document Generator.
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