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Title: Rad-Hydro with a High-Order, Low-Order Method

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Rad-Hydro with a High-Order, Low-Order Method

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Moment-based acceleration via the development of "high-order, low-order" (HO-LO) algorithms has provided substantial accuracy and efficiency enhancements for solutions of the nonlinear, thermal radiative transfer equations by CCS-2 and T-3 staff members [2, 3]. Accuracy enhancements over traditional, linearized methods are obtained by solving a nonlinear, time-implicit HO-LO system via a Jacobian-free Newton Krylov procedure. This also prevents the appearance of non-physical maximum principle violations ("temperature spikes") associated with linearization. Efficiency enhancements are obtained in part by removing "effective scattering" from the linearized system. In this highlight, we summarize recent work in which we formally extended the HO-LO radiation algorithm to include operator-split radiation-hydrodynamics [4].

Background and Motivation

HO-LO methods for single-physics kinetics problems have been demonstrated at LANL with much success. This work formalizes an approach for using HO-LO acceleration on a multiphysics problem, specifically, rad-hydro with a "simple" material motion correction [1]. For HO-LO to be a viable method in multiphysics problems, it is a necessary step to document the algorithm, provide an overview of the implementation in Jayenne and in Eulerian Application Project (EAP) software, verify our results on benchmark problems, and provide results demonstrating its advantages.

Description/Impact

Because thermal transport is an extremely computationally intensive part of High Energy Density Physics (HEDP) problems, enhancements that bring about substantial speedups and accuracy improvements are high-impact. The top figure on the next page depicts a high level description of the HO-LO (blue-pink) radiation solve coupled to the operator-split Eulerian hydrodynamics solve (yellow). The arrows depict the information passed between the different algorithms. We describe the coupling in detail in [4] and provide a verification test on a challenging rad-hydro benchmark problem.

Anticipated Impact

The Al shell figures qualitatively illustrate the statistical noise reduction obtained by using HO-LO Monte Carlo (MC) vs. Implicit Monte Carlo (IMC). The HO-LO solution was also almost twice as fast. This is due in part to a two-fold reduction in the number of AMR cells. Quintupling the number of particles (and runtime) for IMC is not enough to match HO-LO MC's lower cell requirements. Altogether, this indicates that the HO-LO MC method will have a very high impact when it is fully deployed in EAP software.

Path Forward

We intend to follow up on this work with a more quantitative comparison of accuracies and efficiencies in a journal article. We are also continuing the development of the HO-LO method in EAP software for more challenging multiphysics problems, keeping our design goals of accuracy, efficiency, and robustness at the forefront.

Acknowledgements

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References

[1] R. B. Lowrie and A. B. Wollaber. Simple material-motion corrections for thermal radiative transport. *Transport Theory and Statistical Physics*, 43:1–14, 2014.

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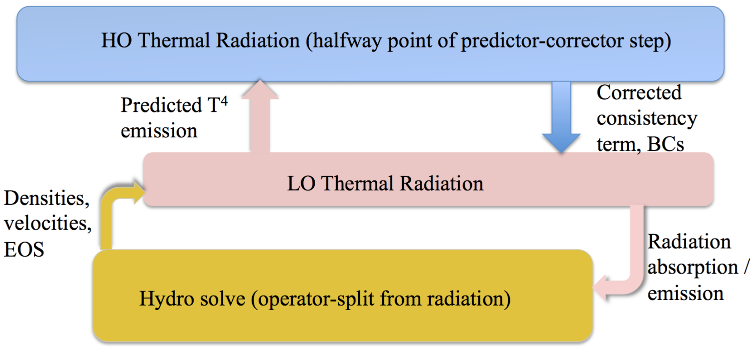
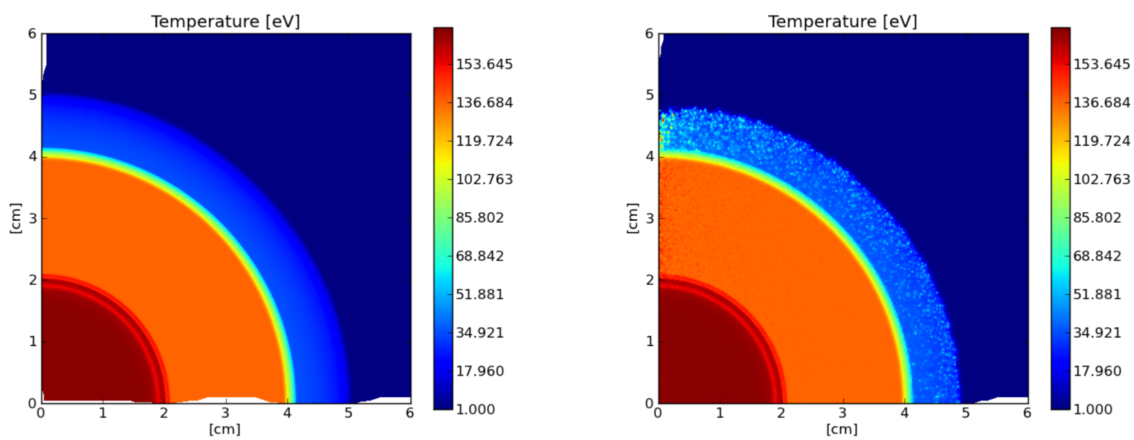
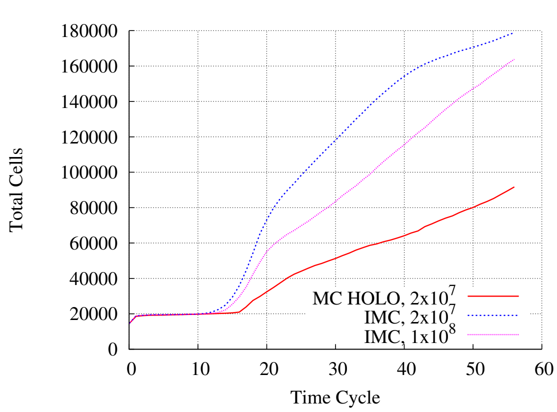


High level overview of HO-LO radiation coupling with hydrodynamics



HO-LO MC (left) and IMC (right) material temperatures for a heated Al shell problem. Note the larger statistical noise for low radii (left); this simulation used the same number of Monte Carlo particles as for HO-LO, but took 1.8 times longer to complete.



Comparison of total number of spatial cells vs. the time cycle in the Al shell problem; note the two-fold reduction in HO-LO MC vs. IMC.

[2] H. Park, J. D. Densmore, A. B. Wollaber, D. A. Knoll, and R. M. Rauenzahn. Monte Carlo solution methods in a moment-based scale-bridging algorithm for thermal radiative transfer problems: Comparison with Fleck and Cummings. In *Proc. ANS Topical Meeting, International Topical Meeting on Mathematics and Computation*, Sun Valley, ID, May 5–9 2013. American Nuclear Society.

[3] H. Park, D. A. Knoll, R. M. Rauenzahn, A. B. Wollaber, and J. D. Densmore. A consistent, moment-based, multiscale solution approach for thermal radiative transfer problems. *Transport Theory and Statistical Physics*, 41:284–303, September 2012.

[4] A. B. Wollaber, H. Park, R. B. Lowrie, R. M. Rauenzahn, and M. A. Cleveland. Radiation hydrodynamics with a high-order, low-order method. In *Proc. ANS Topical Meeting, International Topical Meeting on Mathematics and Computation*, Nashville, TN, April 19–23 2015. American Nuclear Society.