Non-local Electron Transport Validation using 2D DRACO Simulations

D. Cao[1], J. Chenhall[1], E. Moll[1], A. Prochaska[1], G. Moses[1], J. Delettrez[2], T. Collins[2]

[1]University of Wisconsin–Madison [2]University of Rochester Laboratory for Laser Energetics

Abstract: Comparison of 2D DRACO simulations, using a modified version[1] of the Schurtz, Nicolai and Busquet (SNB) algorithm[2] for non-local electron transport, with direct drive shock timing experiments[3] and with the Goncharov non-local model[4] in 1D LILAC will be presented. Addition of an improved SNB non-local electron transport algorithm in DRACO allows direct drive simulations with no need for an electron conduction flux limiter. Validation with shock timing experiments that mimic the laser pulse profile of direct drive ignition targets gives a higher confidence level in the predictive capability of the DRACO code. This research was supported by the University of Rochester Laboratory for Laser Energetics.

Algorithm

On every timestep in DRACO…

1. Solve the following equation for $T^{(k)}$:

$$\rho C_v \frac{T^{(k)}(\vec{r}) - T^n(\vec{r})}{\Delta t} = -\vec{\nabla}\cdot K^n_{SH}\vec{\nabla} T^{(k)}(\vec{r}) + S^{(k-1)}_{ext}(\vec{r})$$

$$k = iteration\ index$$

$$S^{(0)}_{ext}(\vec{r}) = S_{ext}\left(\vec{r}, T^n(\vec{r})\right) = S^n_{ext}(\vec{r})$$

2. Solve the following equation for $H_g(\vec{r})$:

$$-\vec{\nabla}\cdot\frac{\lambda'_g(\vec{r})}{3}\vec{\nabla}H_g(\vec{r}) + \frac{H_g(\vec{r})}{\lambda_g(\vec{r})} = -\frac{\vec{\nabla}\cdot K^n_{SH}\vec{\nabla}T^{(k)}(\vec{r})}{24}\int_{\beta_{g-1}}^{\beta_g}\beta^4 e^{-\beta}d\beta$$

$$g = 1,2,3 \ldots G$$

3. Check the convergence criterion:

$$\sum_{g=1}^{G}\frac{H_g(\vec{r})}{\lambda_g(\vec{r})} \cong \sum_{g=1}^{G}\frac{H_g(\vec{r})}{\lambda_g(\vec{r})}\Big|_{last\ iteration}$$

Note: Do not check for convergence in low density areas

4. If no convergence, update $S^{(k)}_{ext}$:

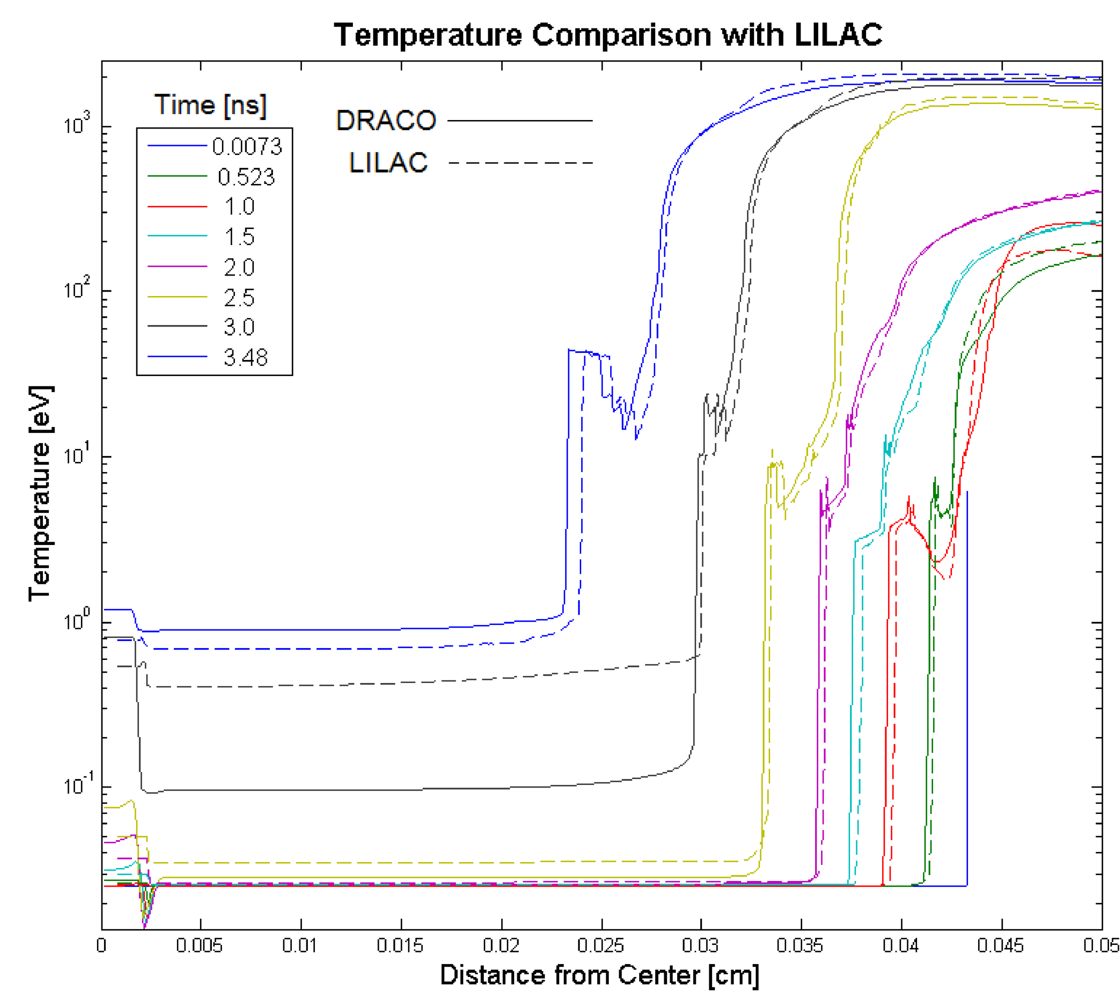
$$S^{(k)}_{ext} = S^{(k-1)}_{ext} + \sum_{g=1}^{G}\frac{H_g(\vec{r})}{\lambda_g(\vec{r})} - \vec{\nabla}\cdot K^n_{SH}\vec{\nabla}T^{(k)}(\vec{r})$$

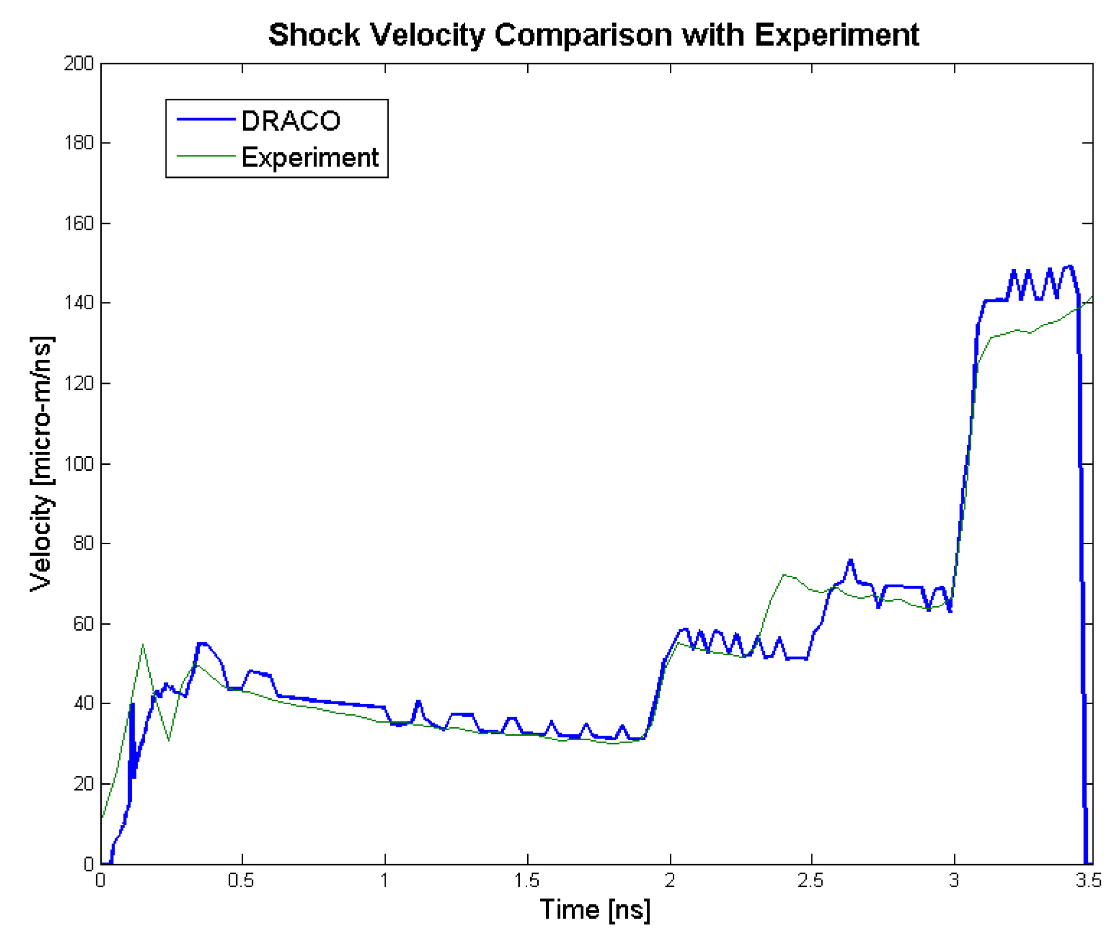
Then go back to step #1 and repeat with next iteration of k ($i.e.\ k \rightarrow k+1$).
Else, stop iteration and set

$$T^{n+1}(\vec{r}) = T^{(k)}(\vec{r})$$

Results

Temperature and shock velocity results from a direct-drive ICF simulation in DRACO with a three-picket laser pulse





Discussion

-Mean free paths are the only physical parameters
- Location of temperature fronts and preheat levels depend on mean free paths
- Mean free paths depend on detailed electron transport physics

-For very small mean free paths, results reproduce Spitzer conduction result

Conclusion

SNB method better matches LILAC results than the flux-limited case. More studies on SNB's potential needs to be done; the mean free paths represent a full optimization function that can be adjusted, and the effects of the number of groups must still be explored.

Acknowledgements

We thank Marty Marinak, LLNL, for his guidance on the algorithm and George Zimmerman, LLNL, for providing guidance on algorithm implementation. Support for this research provided by University of Rochester Laboratory for Laser Energetics.

References

[1] Private communications with M. Marinak and G. Zimmerman, LLNL.
[2] Schurtz, Nicolai and Busquet, "A nonlocal electron conduction model for multidimensional radiation hydrodynamics codes", Phys. Plasmas 7, 4238(2000).
[3] T. Boehly, et. al., "Multiple spherically converging shock waves in liquid deuterium", Phys. Plasmas 18, 092706(2011).
[4] V. Goncharov, et. al., "Early stage of implosion in inertial confinement fusion: Shock timing and perturbation evolution", Phys. Plasmas 13, 012702(2006).

Related Talk – JO4.00013, J.A. Delettrez : Effect of Nonlocal Electron Transport in Both Directions on the Symmetry of Polar-Drive--Ignition Targets