A Lattice Boltzmann Method for the Analysis of Gas Behavior in Hanford Tanks

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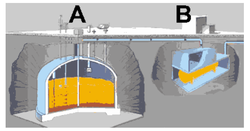
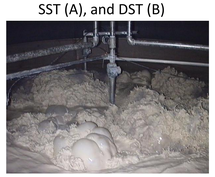
Introduction

- 53 million gallons of radioactive waste at Hanford site
- Stored in leaking single shell tanks (SST)
- Double shell tanks (DST) introduced in 1968
- Unlike the SSTs, DSTs show no leaking
- Waste is being transported from SSTs to DSTs
- Two-phase flow exists in the mixing, handling, and transportation of the liquid waste
- Computer simulations can be used to predict the behavior of gas bubbles in tanks, performance of mixers or spargers, etc.



SST (A), and DST (B)


Rising bubbles mix slurry

Lattice Boltzmann Method

- Lattice Boltzmann method is based on the Boltzmann transport equation
- Domain is discretized with lattice nodes instead of rigorous meshing
- Independence from mesh allows for complex domains like porous media
- Masses at nodes collide and then stream information to neighbors

Collision

$$f_a^t(\mathbf{x},t) = f_a(\mathbf{x},t) - \frac{\left[f_a(\mathbf{x},t) - f_a^{eq}(\mathbf{x},t)\right]}{\tau}$$

...where...

$$f_a^{eq}(\mathbf{x}) = w_a \rho(\mathbf{x})\left[1 + 3\frac{\mathbf{e_a}\bullet\mathbf{u}}{c^2} + \frac{9}{2}\frac{(\mathbf{e_a}\bullet\mathbf{u})^2}{c^4} - \frac{3}{2}\frac{\mathbf{u}^2}{c^2}\right]$$

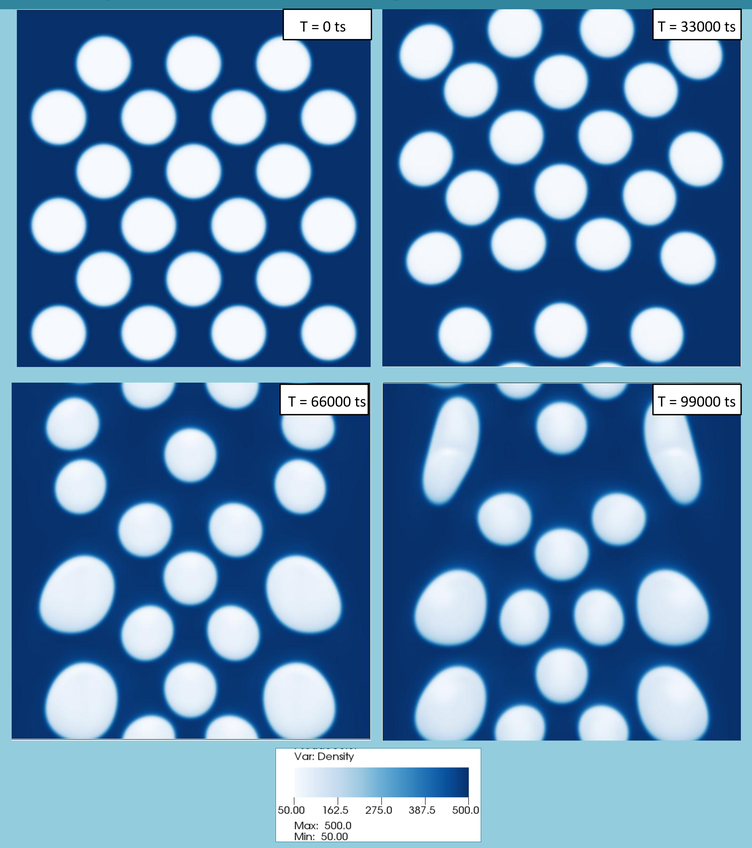
Stream

$$f_a(\mathbf{x}+\mathbf{e_a}\Delta t, t+\Delta t) = f_a^t(\mathbf{x},t)$$

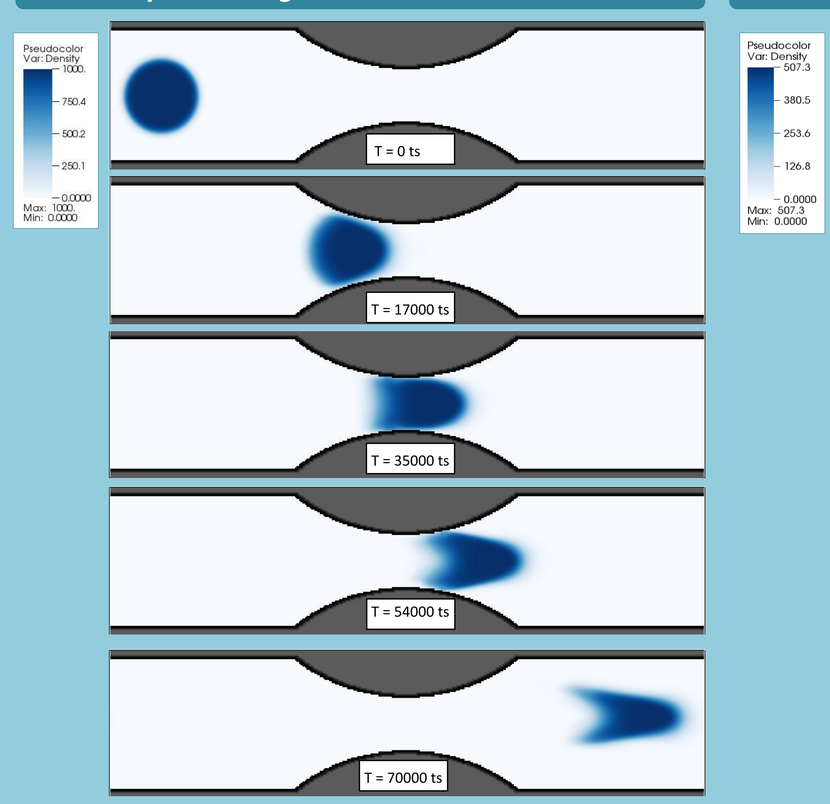
Current Status and Future Directions

- FIU developed a three-dimensional, parallelized LBM code that provides two-phase flow simulations accurately and efficiently as compared to classical CFD methods
- The code allows integration of complex piping geometry that can be found in Hanford tanks as well as their capturing their interactions with the fluid phases
- In addition, contact line dynamics of the fluid interface at the solid surfaces can also be predicted
- Future work will include implementation of a turbulence model as well as the capability to simulate non-Newtonian effects of the sludge

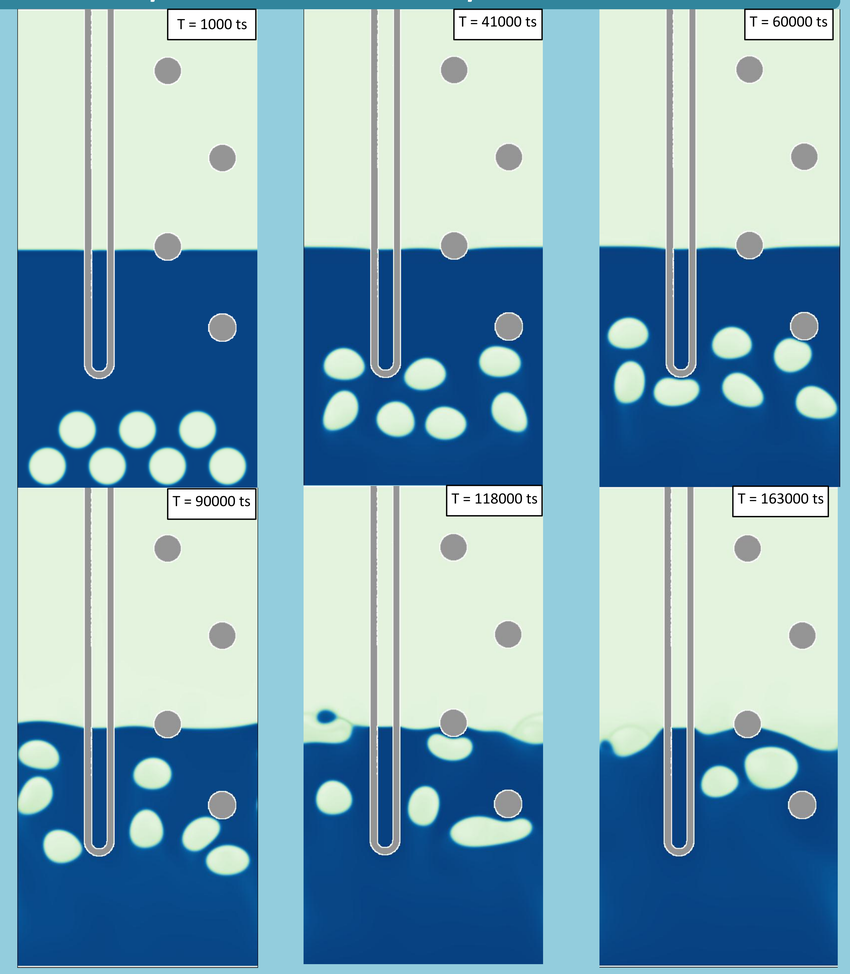
Buoyant Gas Bubble Rising in a Periodic Domain



Droplet through a Constricted Channel



Multiphase Fluid Flow in Complex Geometries



Acknowledgements

This research was supported by the U.S. Department of Energy through the DOE-FIU Science and Technology Workforce Development Program, under grant No. DE-EM0000598.

Special thanks to Leonel Lagos, Ph.D., PMP ®, Director of the DOE-FIU Science and Technology Workforce Development Program