Parallel implementation and scalability analysis of turbulent particle laden flow modeling with particle hydrodynamic interactions using 2D domain decomposition

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Numerical Weather Prediction uses modeling to account for cloud droplets grow to rain drops. To improve this modeling, it is important to understand the droplet growth mechanism.
Before water drops could fall down as rain, two distinguished mechanisms help droplets grow in size: diffusional growth and growth by collision and coalescence. It has been known that cloud turbulence could make a substantial impact on the growth by collision. To accurately measure this, Ayala *et al*. (2008) developed a hybrid direct numerical simulation (HDNS) to quantify turbulent collision- coalescence. They made used of Pseudo Spectral Method (PSM) to model the turbulence and a Lagrangian scheme to follow each of the droplets in the flow. In addition, they allowed the particles to locally interact among them through the shared fluid by analytically modeling the flow around the droplets using Stokes Flow. Although this HDNS is the most accurately tool available, it suffers of some restrictions. It has the range of scales limitation known to PSM and it is computationally very expensive. It is desirable to extend the range of scales or equivalently the flow Reynolds number so a more complete understanding of related physical processes can be obtained. To this end, the HDNS has been parallelized using a 2D domain decomposition scheme. In this talk, detailed implementation issues related to multi-dimensional domain decomposition to parallelize the HDNS code will be discussed. I will show scalability data obtained from several parallel computers and address a theoretical scalability analysis through a complexity analysis we developed to understand performance on the state-of-the-art PetaScale computers with O(100,000) processors. I will also talk about code limitations and possible future improvements.

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