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Numerical Simulations of Complex Multiphase Flows: Opportunities and Challenges

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Abstract **-** Multiphase flows are a critical for industrial and natural processes, including the and vapor generation in power plants, combustion of liquid fuels, processing of chemicals in bubbles columns, rain, and heat and mass exchange between the oceans and the atmosphere. Predicting their behavior is therefore of outmost interest. Direct numerical simulations, where the governing continuum equations are solved accurately for systems that are large enough so that meaningful statistical quantities can be computed, are rapidly becoming routine, at least for systems where the physics is simple enough, such as disperse flows of bubbles and drops. Those simulations yield enormous amount of data that, in addition to providing physical insights, opens up new opportunities for the development of lower order, or coarser, models that describe the average or large-scale behavior. We discuss efforts to do so, including the use of machine learning to extract closure models from the data for bubbly flows, as well as classify different flow regimes. In addition, success with relatively simple systems calls for simulations of more complex problems. Multiphase flows often produce features such as thin films, filaments, and drops that are much smaller than the dominant flow scales and are well-described by analytical or semi-analytical models.

Recent efforts to combine semi-analytical models for thin films using classical thin film theory, and to compute mass transfer in high Schmidt number bubbly flows using boundary layer approximations, in combination with fully resolved numerical simulations of the rest of the flow, are described.