PURDUE
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School of Aeronautics and Astronautics

The AAE Spring 2010 Colloquium Series

COLLOQUIUM

Large Eddy Simulation of Two-Phase Flows with Evaporation

Josette Bellan
Senior Research Scientist, Jet Propulsion Laboratory
California Institute of Technology

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3:00 P.M.
ARMS 1109

Abstract

Achieving the accurate simulation of two-phase turbulent flows has been a long-standing and elusive goal. Applications of such simulations include particle dispersion in the atmosphere, tornadoes, sand storms, motion of schools of fish, and devices based on spray operation (e.g. household cleaning products, pharmaceutical inhalers, office printers, gas turbine engines, spray-chemical-conversion reactors). In all these applications, the character of the flow is determined by momentum and energy interactions between the two phases; sometimes, mass transfer interactions are also important. These interactions occur at scales much smaller than the large scale of interest, and existing simulation methods cannot resolve both the small and large scales. The method of Large Eddy Simulation addresses this difficulty by applying a spatial filter to obtain the equations at the large scales; these equations include terms resulting from averaging over the small scales. The averaged terms cannot be computed from the large scales and must be calculated using specifically constructed models characterizing the flow and the drops/flow interactions at the small scales.

To construct these models, the tool of Direct Numerical Simulation is used. Direct Numerical Simulation is a computational method where all scales of the flow are calculated, but this is feasible only for Reynolds numbers smaller than those in the fully turbulent regime. It is shown how Direct Numerical Simulation can be used in two ways: First, it can be utilized to create a database from which models can be assessed that characterize the essence of the small-scale behavior. Because it is found that the drops-to-flow interaction is of leading order in the dissipation, particular attention is devoted to models describing this interaction. The models of the small scales are then utilized to replace the averaged terms in Large Eddy Simulation where they are coupled to the large scales. Stability and accuracy of the Large Eddy Simulations verifies whether this coupling is physical, and thus establishes the appropriateness of the models. Second, Direct Numerical Simulation serves as a benchmark to Large Eddy Simulation in that the accuracy of the latter is defined with respect to the results of the Direct Numerical Simulation at the larger scale of the Large Eddy Simulation. It is found that two models of the small scales satisfy the stringent criterion of temporal and spatial equivalence of Large Eddy Simulation with Direct Numerical Simulation. The computational savings of the Large Eddy Simulations, up to 300-fold compared to the Direct Numerical Simulation, offer the possibility of accurate simulations of fully turbulent two-phase flows with evaporation.

An informal coffee & cookie reception will be held prior to the lecture at 2:30 p.m. in the AAE/ARMS undergraduate lounge (directly in front of ARMS 3rd floor elevators)

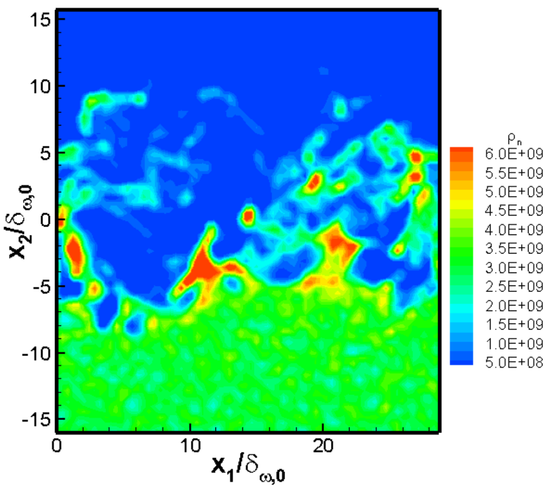

Fig. 1. Drop number density. Filtered and coarsened Direct Numerical Simulation (~16x10^6 nodes; 2252 Central Processor Unit hours).

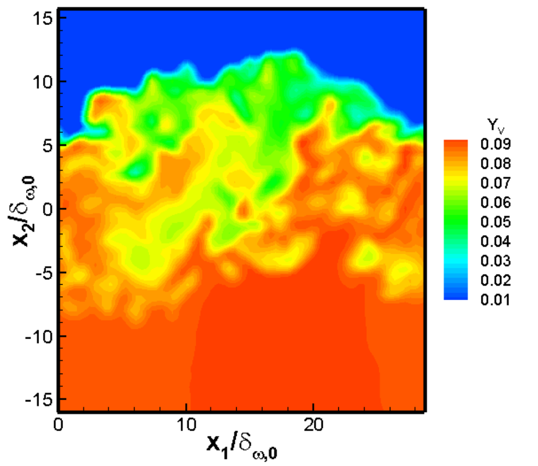

Fig. 2. Mass fraction of the evaporated liquid. Filtered and coarsened Direct Numerical Simulation, as in Fig. 1.

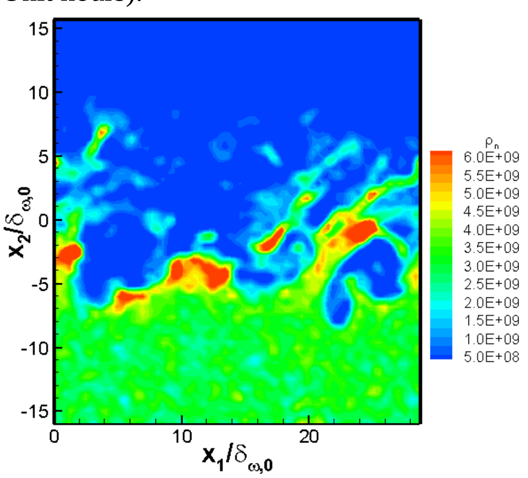

Fig. 3. Drop number density. Large Eddy Simulation (~2.5x10^5 nodes and 8-fold reduction in drop number; 37 Central Processor Unit hours).

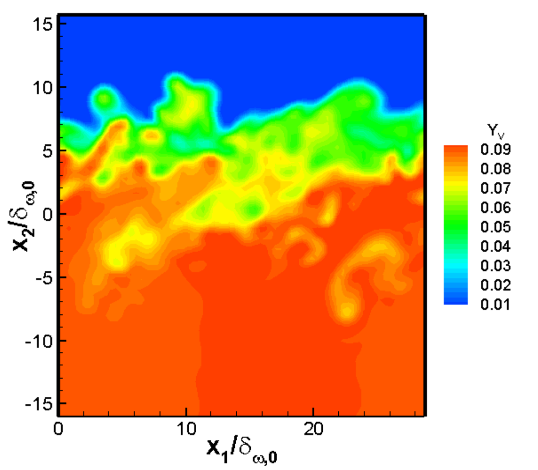

Fig. 4. Mass fraction of the evaporated liquid. Large Eddy Simulation, as in Fig. 3.

Biography:

Dr. Josette Bellan did her undergraduate studies and part of her graduate studies at the University of Sciences of Paris in Applied Mathematics and Continuum Mechanics. She received her Ph.D. from Princeton University in the Department of Mechanical and Aerospace Engineering, specializing in Fluid Mechanics and Combustion.

Dr. Bellan is a currently Senior Research Scientist, Jet Propulsion Laboratory where she has performed research since 1978, and is since 1995 a Visiting Associate in the Division of Engineering and Applied Science at the California Institute of Technology (Caltech). Her fields of interest are Multiphase Flow Phenomena, Fluid Behavior, Phase Change, Heat Transfer and Combustion. She has published extensively in refereed journals, has written chapters in books, and has given numerous invited talks, including three European missions sponsored by NATO's Research and Technology Agency. She was a Lecturer at Caltech and a Chancellor's Distinguished Lecturer at the University of California, Irvine.

Dr. Bellan is a Fellow of ASME and of AIAA where she previously chaired the Propellant and Combustion Technical Committee. She is also a member of the Combustion Institute where she serves on the Advisory Committee for the International Symposium on Combustion, and she is a member of ILASS Americas where she served on the Board of Directors. Dr. Bellan is Deputy Editor of *Progress in Energy and Combustion Science*, on the Editorial Board of *Atomization and Sprays* and was Associate Editor for the *AIAA Journal* from 1998 to 2004. She is an Amelia Earhart Fellow and the recipient of the Marshall Award for the best paper from the Americas at ICLASS 2000.