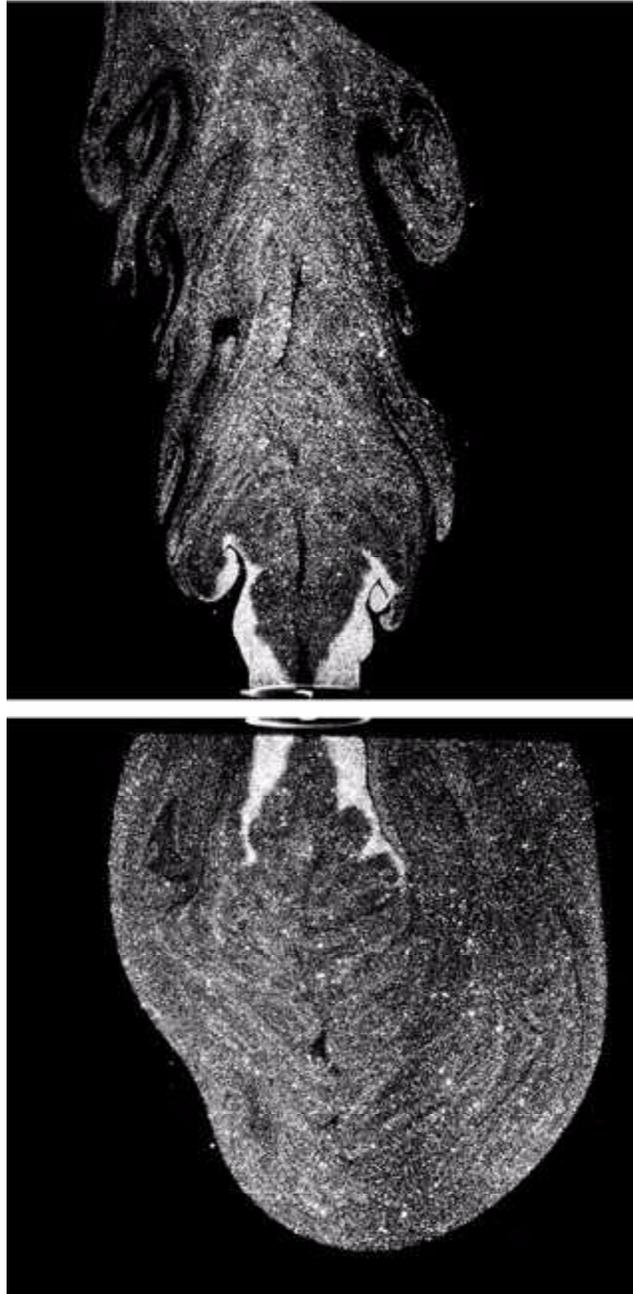
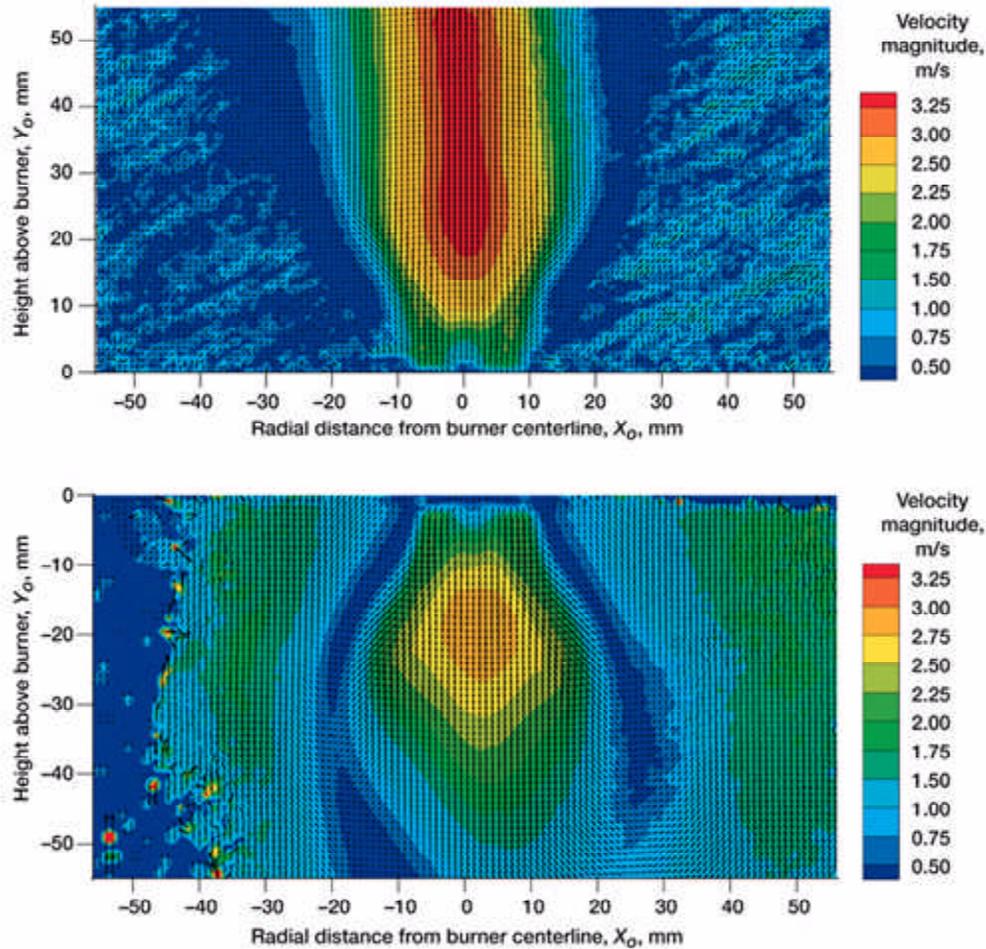


Field Effects of Buoyancy on a Premixed Turbulent Flame Studied by Particle Image Velocimetry



Flow-field images. Top: 1g. Buoyancy forces aligned with the flow direction augment instabilities in the products plume. Bottom: -1g. The importance of buoyancy is clear as reversing the flow direction suppresses instabilities and dramatically alters the flow field.

Typical laboratory flames for the scientific investigation of flame/turbulence interactions are prone to buoyancy effects. Buoyancy acts on these open flame systems and provides upstream feedbacks that control the global flame properties as well as local turbulence/flame interactions. Consequently the flame structures, stabilization limits, and turbulent reaction rates are directly or indirectly coupled with buoyancy. The objective of this study is to characterize the differences between premixed turbulent flames pointing upwards (1g), pointing downwards (-1g), and in microgravity (μg). The configuration is an inverted conical flame stabilized by a small cone-shaped bluff body that we call CLEAN Flames (Cone-Stabilized Lean Flames). We use two laser diagnostics to capture the velocity and scalar fields. Particle image velocimetry (PIV) measures the mean and root mean square velocities and planar imaging by the flame fronts method outlines the flame wrinkle topology. The results were obtained under typical conditions of small domestic heating systems such as water heaters, ovens, and furnaces. Significant differences between the 1g and -1g flames point to the need for including buoyancy contributions in theoretical and numerical calculations. In Earth gravity, there is a complex coupling of buoyancy with the turbulent flow and heat release in the flame. An investigation of buoyancy-free flames in microgravity will provide the key to discern gravity contributions. Data obtained in microgravity flames will provide the benchmark for interpreting and analyzing 1g and -1g flame results.



Preliminary PIV results. Top: 1g. Bottom: -1g.

This study is being conducted by the Lawrence Berkeley National Laboratory, with project management and assistance in hardware development, engineering feasibility, and other efforts provided by the NASA Glenn Research Center. The study is focusing on lean premixed combustion, which is a proven method to reduce the formation of pollutants such as nitrogen oxides (NO_x). However, its adaptation to many industrial heating systems is prone to buoyancy influences that affect heat distribution, system reliability, and even safety provisions. At present, only rudimentary knowledge is available to guide combustion engineers to avoid or overcome buoyancy problems. In addition, turbulent combustion is considered to be the most important unsolved problem in combustion science, and current theoretical and numerical combustion models cannot handle buoyancy effects yet. Our research will benefit both combustion science and technology. Experimentalists will gain new insights for identifying and interpreting buoyancy contributions to laboratory flames. Theoretical and numerical researchers will have a set of reference data to improve the fidelity of turbulent combustion models and to develop methods to address the problems of flame/chamber coupling. Combustion engineers will gain scientifically based scaling information to handle buoyancy influences on practical systems.

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