Developing an Apparatus to Study On-Demand Turbulent Buoyant Jets in the Lab

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Turbulent buoyant jets are complicated physical phenomena that play an important role in the transfer of heat and chemicals in a variety of environmental settings. They occur over a large range of size scales, with nozzle diameters on the order of 1 cm for seafloor vents to diameters on the order of 1 km for erupting stratovolcanoes. Seafloor hydrothermal vents are natural examples of turbulent buoyant jets, where geothermally heated water flows out of oceanic crust into the overlying ocean, creating plumes of mineral-rich hot water which rises and spreads in the water column. These vents can support diverse ecosystems in areas where no sunlight penetrates, and thus are of great importance to the study of primitive life forms. However, they are usually located along mid-ocean ridges at depths of several kilometers, so observing them directly is difficult. Much progress has been made using video image analysis techniques to study turbulent buoyant jet properties, including their volumetric flow rates. In this project we created a simple, inexpensive, easy to operate turbulent buoyant jet simulator in the lab. Using this apparatus, we were able to make plumes with various properties on demand for study using video image analysis. The apparatus injects gas—currently nitrogen or carbon dioxide, or some mixture of the two—into the air after seeding it with water vapor to make the plume visible and passing it through a rough nozzle to generate turbulence. We have been collecting high-resolution videos of these plumes and using the video to refine our knowledge of the theoretical behavior of such plumes and our techniques for measuring their properties. In particular, we have been working on methods for tracing the trajectory of a horizontally injected plume, matching theoretical models for plume trajectory to the traced trajectory, and estimating flow rate based on trajectory.