Properties of vertical plumes emanating from oceanic hydrothermal springs using LES

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Buoyant plumes rising from hydrothermal sources play an important role for the mixing and transport of biological and chemical tracers in the deep ocean, at multiple scales ranging from the vent exit to the neutral buoyancy level. In this study, we perform LES using the Basilisk code and its adaptive grid technique to investigate the different existing conditions of hydrothermal plumes at very high-resolution, reaching the centimeter scale. To capture the extreme and highly unstable behavior of the 300°C seawater injection, we reconstruct a non-linear equation of state, based on measurements, which helps to provide an estimate of the heat flux and reduce uncertainties. We show that these non-linearities are crucial for representing the plume dynamics. They help to induce a braking effect on the plume, as well as a higher level of turbulence, resulting in a high mixing efficiency of $\eta \sim 0.7$. This finding strengthens the idea that the mixing efficiency is much higher in some regions of the ocean. Furthermore, we show that the fully-turbulent state observed at the vent exit is primarily driven by the energy injected by the subsurface circulation, highlighting the need for a turbulence parametrization. The corresponding TKE injected at the seafloor is determined. Moreover, key plume parameters are retrieved from in-situ observations, including the buoyancy flux, by comparing the plume width and its transition zone from forced plume to fully buoyant plume with the results obtained from the LES. Overall, our study provides a comprehensive understanding of hydrothermal plumes and their behaviors.

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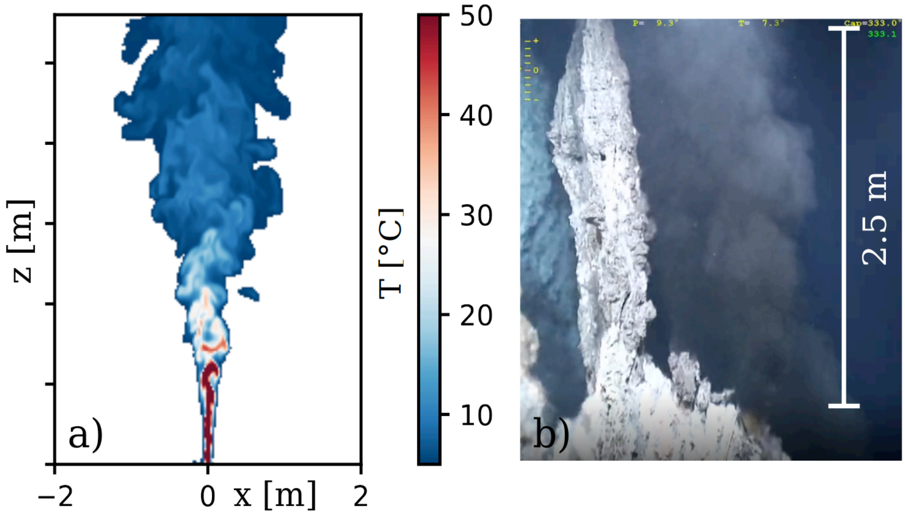

Figure 1: (a) Fully turbulent plume in LES. (b) On-site video capture.