On a wall plume in a closed cavity

T. Caudwell*, J. B. Flór, M. E. Negretti

LEGI, CNRS, UJF/Grenoble-INP,
BP 53 38041 Grenoble Cedex 9, France

Wall plumes are generated along vertical heated surfaces and are common in many situations in the environment, industry, and buildings. The resulting convective motion is relevant for ventilation control, heat distribution or transfers, as well as the dispersion of pollutants. Plumes and the related stratification have been considered in former related work in [1, 2, 3, 4, 5], and more recently [6].

In this paper we consider the flow in a 60-cm-high water tank of 60$\times$30-cm^2 horizontal cross section induced by a heated vertical wall with an imposed constant temperature, and investigate the plume structure and formation of the heat stratification in the interior. The evolution of the plume near the wall and the temperature stratification (fig.1a and b) are directly measured across a plane, using the Laser Induced Fluorescence method with a high precision of $\pm$0.2°C. As far as we know, this method has not been exploited before for the measurement of convective motions and appears to be very powerful, in particular when combined with simultaneous Particle Image Velocimetry measurements which enable a precise description of the dynamics of the system through instantaneous or averaged values.

Observations give access to dynamics and patterns within the stratified medium, and to the turbulent plume structure in interaction with the ambient stratification. Using thus obtained results, we present a precise description of the initial and long term evolution of the stratification generated by a rising plume at a heated wall (fig.1c).

A model derived from plume theory [1] has been adapted to the case of a constant temperature boundary condition. The detailed experimental data allows to confront each of the key variables (volume, momentum and buoyancy fluxes) with the model predictions to highlight its strengths, weaknesses and limits. Based on experimental observations, some improvements concerning the entrainment coefficient and the wall shear stress have been suggested.

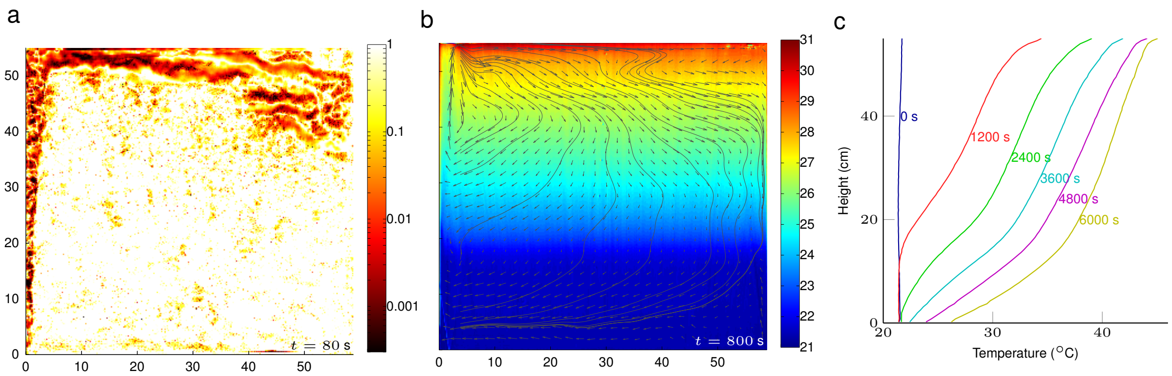

Fig. 1: (a) Local Richardson number of the plume indicating the regions of mixing in the plume along the side wall and top boundary. (b) Circulation in the cavity between the plume and stratification once an upper stratified layer has formed, and (c) the evolution of the stratification profile in time.

References

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*corresponding author: tobit.caudwell@legi.cnrs.fr