Numerical Investigation of Evolution of Plume Structure in Rayleigh-Benard Convection

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Abstract

Numerical Investigations were carried out to study the Evolution of plume structure in Rayleigh-Benard convection at a constant Pr = 5.2 (water) and over a range of Rayleigh number $4.43 \times 10^5 < Ra_H < 7.95 \times 10^8$. Three domains of cross-section 15 cm × 15 cm and height of 5 cm, 10 cm and 20 cm were used to study the plume structure rising from the thermal boundary layer over the high-temperature bottom plate. Transient simulations were carried out in ANSYS Fluent to study the evolution of plume structures. Four different regimes where observed viz, initiation phase; characterised by stable boundary layer across the planform, impingement phase; characterised by the destabilisation of the boundary layer and impingement of bulk flow, plume formation phase; characterised by the formation of line plume from the boundary layer, and plume dynamics phase; characterised by the lateral movement of plume, formation of new plumes and merging of plumes. Total length of plume (L_p) and plume thickness (t_p) were measured from the planforms, and mean plume spacing (λ) and plume area ratio (A_p/A) were calculated using $\lambda = A/L_p$ and $A_p/A = t_p \times L_p / A$. Total length of plume was found to increase with RaH, whereas mean plume thickness was found to decrease with Ra_H; these opposing trends result in plume area ratio nearly independent of Ra_H.

Keywords

Convection, plume structure, boundary layer, plume spacing, length of plumes, plume thickness, and plume area ratio.