10th Australasian Natural Convection Workshop (10ANCW)
Auckland, New Zealand, 30 November - 1 December 2017

# On the Onset of Horizontal Convection

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## 1. INTRODUCTION

Horizontal convection (HC) is a class of natural convection which develops a circulatory convective flow motion for a fluid which is driven by a non-uniform heating condition along a horizontal boundary. The unique characteristic of horizontal convection for overturning the flow by just the heat diffusion along one horizontal boundary, makes this class of natural convection different from other types of it [1-3]. One aspect of interest relating to horizontal convection is its transient behaviour [3-4]. Since most of the previous work studied the quasi-equilibrated HC [1, 2 , 4], this early transient regime needs more attention for understanding the early start-up mechanism, transient regimes and features during the onset of HC, and transition to unsteady flow and turbulent flow. More recently, this transient behaviour was studied for the onset of HC where different time scaling for this onset process were reported experimentally [5]. Flow features during the onset process and the effect of increasing flux Rayleigh number $Ra_F$ was studied and three stages during the onset process were identified: Conduction-dominant regime, Rayleigh–B́enard regime and longitudinal rolls [5].

## 2. APPROACH

The problem considered in this research is the horizontal convection of fluid with $Pr$=6 in a two-dimensional rectangular box of length $L$ and height $D$ with aspect ratio $D/L$=0.5. The side and top walls are insulated, and a no-slip condition is imposed on all boundaries. The bottom boundary is split into two sections, where one half is cooled with uniform temperature and the other half is heated with constant flux. It is supposed for initial state that the fluid is quiescent at a temperature equal to the temperature of the cold boundary $T_{\text{cold}}$. A Boussinesq approximation of the fluid buoyancy is implemented to the governing Navier–Stokes equations, while density differences in the fluid are neglected except the gravity. The Boussinesq flow is computed on a two dimensional domain using a high-order in-house solver, which employs a spectral-element method for spatial discretisation and a third-order time integration scheme based on backwards-differencing.

## 3. RESULTS

Transient features during the onset of horizontal convection at different times are shown in figure 1. Contours of temperatures are shown for $Ra_F$ =1e12 at different time ratios $t/T$, where $T$ represents the time that it takes for the thermal boundary layer to establish. Five regimes during the onset process are shown at (a) $t/T$=0.3 the conduction and plume formation regimes during which the diffusive growth of thermal boundary layer is followed by generation of plumes on the bottom half right boundary (b) at $t/T$=0.5 Rayleigh–B́enard regime which is the unstable transition part of onset process where thermal boundary layer becomes unstable and a row of small plumes forms over the hot end of bottom boundary (c) at $t/T$=1 the rise and eruption of plumes where they shift toward right and top sides of enclosure while a vertical heat-up occurs during this regime and (d) at $t/T$=2 the overturning circulation regime which is the final stage of the transient process. During this regime, flow driven by erupted plumes circulates toward the left half of enclosure which leads to a strong overturning circulation throughout the whole enclosure. This overturning circulation is a main characteristics of HC that occurs for different range of $Ra_F$ during the onset process.

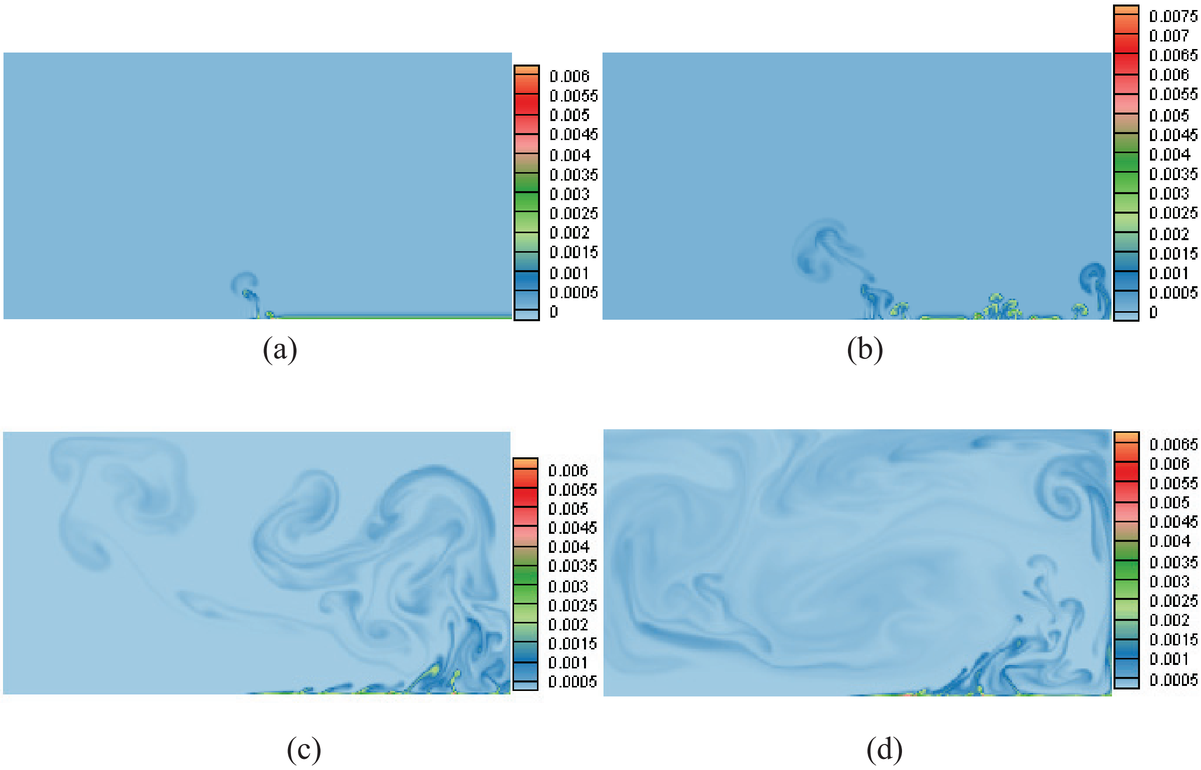


**Figure 1.** Contours of temperature indicating the transient features evolving through the onset process for $Ra_F$ =1e12 at *t/T* (a) 0.3, (b) 0.5, (c) 1, (d) 2.

## 4. CONCLUSION

Transient features during the onset of horizontal convection was studied to characterise the different flow features observed during the initial stages of development. Contours of temperature for different time frames are observed and analysed at $Ra_F$ =1e12 and distinct transient features are distinguished. Five distinct regimes are identified for the onset of horizontal convection: conduction regime, formation of plumes, Rayleigh–Bénard convection regime, rise and eruption of plumes and overturning circulation regime. This abstract highlights the importance of onset process and transient features that occurs during the onset of horizontal convection at high Rayleigh numbers for transition to turbulence and transition to instability before leading to a quasi-equilibrated state for a better understanding of this class of natural convection.

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