Two- and three-dimensional multiple steady states in a porous cavity heated and salted from below

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1. Introduction

Double-diffusive natural convection in porous media saturated with binary fluids has received growing attention owing to the practical importance of the phenomenon in various natural and industrial applications. In such problems, convection (also referred to as thermosolutal convection) is driven by simultaneous temperature and concentration gradients. Moisture migration in fibrous insulation, drying processes, transport of contaminants in saturated soil, grains storage installation, food processing, electrochemical processes, etc. are some examples implying thermosolutal convection. A comprehensive review of the literature concerning experimental and theoretical studies of double-diffusive natural convection in saturated porous media is documented in the recent books by Vadasz (ed.) [1], Nield and Bejan [2], Ingham and Pop (eds.) [3] and Vafai (ed.) [4].

In the literature, numerous papers of early published works on double-diffusive convection have dealt with the two-dimensional approach and are concerned with vertical [5–9] or horizontal [10–14] cavities submitted to various thermal and solutal boundary conditions. Comparatively, the three-dimensional model has been considered in few studies where the limitations of the 2D model have been outlined. Earlier, Kimura et al. [15] have extended their previous 2D transient convection [16] conducted in a square cross-section of fluid-saturated porous material heated from below to three-dimensional convection in a fluid-saturated cube of porous material using the same numerical approach (a pseudo-spectral numerical scheme). Both similarities and differences between two-dimensional and fully three-dimensional modes were observed and discussed. It is found that the occurrence of a transition from more complex to less complex flows is common features of two- and three-dimensional convection. We learn also in this study that there are quantitative differences between two- and three-dimensional convection and a number of characteristics is observed only in the three-dimensional convective mode. From their side, Sezai and Mohamad [17] used a three-dimensional mathematical model based on the Brinkman extended Darcy equation to study double-diffusive natural convection in a fluid-saturated porous cubic enclosure subject to opposing and horizontal gradients of temperature and concentration. The flow is driven by conditions of