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Horizontal rolls in a convective flow driven by differential heating

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Secondary flows in the form of horizontal rolls are a common feature of a large variety of flows of different nature and scale. Roll vortices are often observed in the atmospheric boundary layer. Depending on their size and strength, rolls play a significant role in transporting momentum, heat and moisture through the atmospheric boundary layer. Our aim is to study the problem of horizontal rolls generation in a natural (not mixed) convective flow above a partially heated surface in a closed domain with a free surface. Horizontal rolls, generated in convective flow above a partially heated bottom in a rectangular box are studied experimentally for a wide range of the Prandtl number ($7 \leq \mathrm{Pr} \leq 1020$), the Rayleigh number ($300 \leq \mathrm{Ra} \leq 2.8 \cdot 10^7$) and the aspect ratio ($0.08 \leq a \leq 0.7$). Experimental studies are supported by direct numerical simulations, which made possible the examination of the regimes inaccessible in the experiment, and also to investigate in detail the heat transfer in the convective flow. A variety of regimes with longitudinal helical rolls, with transverse rolls and with mixed structures has been observed. The structure of secondary flows is defined by the level of convective supercriticality in the boundary layer (Rayleigh number) and the intensity of the throughflow, defined by the Reynolds number, which depends itself on the heating and size, i.e. on the Rayleigh number. Though the Reynolds number is not a governing parameter in a proper sense, we succeeded to clear separate domains with different kinds of rolls on the Reynolds – Rayleigh numbers plane only. The transverse rolls appear in the flow only under the conditions of the large vertical drop in the temperature and weak large-scale flow (that is possible only at large values of the Prandtl number). Both longitudinal and transverse rolls lead to remarkable heat transfer enhancement. The formation and characteristics of horizontal rolls are described in details.