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The influence of streamwise-aligned ridges on the dynamics of convective rolls

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The present study investigates the influence of streamwise-aligned ridges on the formation and dynamics of convective rolls in a turbulent channel flow. The analysis is carried out by solving the Navier-Stokes equation under the Boussinesq approximation by means of direct numerical simulation (DNS). Convective rolls arise as streamwise elongated large-scale structures in mixed convection flows, when shear and buoyancy effects contribute similarly to the heat and mass transfer. They appear as counter-rotating rolls in the channel cross-section, which is illustrated in figure 1 (a). In our recent study[1], the influence of streamwise-aligned ridges on the flow organization of mixed convection flows was systematically investigated. On the one hand, it was shown that ridges can significantly shift the transition region between the different convection regimes with respect to the bulk Richardson number Ri_b. On the other hand, it was observed, that ridges can induce a slow lateral meandering of the convective rolls which is not apparent for smooth wall conditions (shown in figure 1 (b)). This meandering occurs for $Ri_b = 1$ and spanwise ridge spacings S, which are in the order of the spanwise wavelength of the convective rolls, e.g. $S = 4\delta$ and $S = 8\delta$, where δ is the half-channel height. The hypothesis is, that ridges support the formation of up- and downdrafts, such that they occur preferentially at the ridge location. However, the symmetrical ridge arrangement leads to the situation that up- and downdrafts are supported on opposite ridges and thus counteract each other, resulting in the lateral meandering of the convective rolls. In this article, the hypothesis is tested further, for example by examining ridge arrangements where the ridges on the upper wall are removed. As can be seen in figure 1, the single ridge on the bottom wall with $S = 8\delta$ can fix the spanwise position of the updraft in time, while for the symmetric arrangement the lateral meandering is observed. The comparison of the mean temperature in figure 1 (top row) between both cases shows that the fixation of the convective roll leads to a stronger mean up- and downdraft. At the conference further investigations will be presented, for instance, staggered ridge arrangements which allow us to examine if ridges might be able to modify the natural spanwise wavelength of convective rolls. The outcome of this investigation will help to advance our understanding of the formation mechanism of convective rolls and how structured surfaces can alter their appearance and heat and momentum transfer properties.

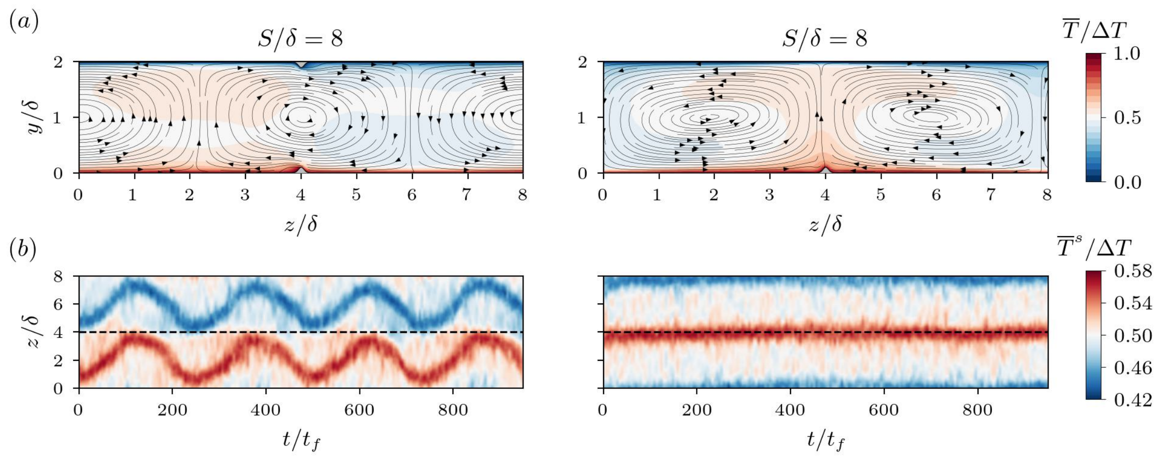

Figure 1: Mean temperature in channel cross-section in (a) and short-time and streamwise averaged temperature over time and spanwise position at channel centre ($y = \delta$) in (b) for different ridge arrangements. Left column shows the arrangement with ridges at the bottom and top wall, while the right column depicts the arrangement with ridges at the bottom wall. In (b) the black dashed line indicates the spanwise position of the ridges.

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[1]Schäfer et al., *Journal of Fluid Mechanics* **950** (2022).