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Three-dimensional Rayleigh-Darcy convection at high Rayleigh numbers

Monday, 30 May 2022 16:35 (15 minutes)

We perform large-scale numerical simulations to study Rayleigh-Darcy convection in three-dimensional fluid-saturated porous media up to Rayleigh-Darcy number Ra=80,000. At these large values of Ra, the flow is dominated by large columnar structures - called megaplumes - which span the entire height of the domain. Near the boundaries, the flow is hierarchically organised, with fine-scale structures interacting and nesting to form larger-scale structures called supercells. We observe that the correlation between the flow structure in the core of the domain and at the boundaries decreases only slightly for increasing Ra, and remains rather high even at the largest Ra considered here. This confirms that supercells are but the boundary footprint of megaplumes dominating the core of the domain. In agreement with available literature predictions, we show that the thickness of the thermal boundary layer (d) scales very well with the Nusselt number (Nu) as d~1/Nu. Measurements of the mean wave number - inverse of the mean length scale - in the core of the flow support the scaling Ra^0.49, in very good agreement with theoretical and numerical predictions. Interestingly, the behaviour of the mean wave number near the boundaries scales as Ra^0.81, which is distinguishably different from the presumed linear behaviour. We hypothesise that a linear behaviour can only be observed in the ultimate regime, which we argue to set in only at Ra in excess of 500,000, whereas a sublinear behaviour is recovered at more modest Ra. The present results are expected to help the development of long desired reliable models to predict the large- and fine-scale structure of Rayleigh-Darcy convection in the high-Ra regime typically encountered in geophysical processes, as for instance in geological carbon dioxide sequestration.

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References

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Online

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