Multistability in Centrifugal Convection

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Abstract

We systematically investigate the multiplicity of flow states in Centrifugal Convection (CC) within an annular container, heated at the outer sidewall and cooled at the inner wall, under constant vertical-axis rotation. This setup mimics the Annular Centrifugal Rayleigh–Bénard Convection (ACRBC) experiments conducted in Chao Sun's lab at Tsinghua University. For a fixed size of the container and a given fluid, the strengths of centrifugal and thermal driving in such a system are characterized, respectively, by the dimensionless Froude number *Fr* and Rayleigh number *Ra*. Our direct numerical simulations (DNS) span 2×10ˆ5 $\leq$ *Ra* $\leq$ 10ˆ7 for $Fr = 10$ and 100. The results show that the final state sensitively depends on the initial condition, leading to pronounced multistability and substantial variations in heat and momentum transport, while the range of attainable states is strongly restricted. We derive a theoretical estimate of the admissible roll numbers based on the Friedrichs inequality and demonstrate quantitative agreement with the DNS. We further show that, for larger Ra, the range of possible states shrinks systematically due to an elliptical instability, providing a predictive framework for the selection and disappearance of coherent roll states in centrifugal convection.

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