POD Analysis of Bifurcations in Free Convection Flow

The free convection flow in a closed rectangular region with the top surface maintained at a temperature different from that of the vertical walls can display multicellular behavior. The behavior of the flow in these cells ranges from steady laminar through chaotic behavior to steady oscillations as the Rayleigh number increases. The frequency can show a Hopf bifurcation in which frequency doubling/halving occurs as the flow moves from one state to another.

A detailed spectral analysis has been performed, which shows a dynamic system behavior beyond the Hopf bifurcation that was not previously observed experimentally. The wider Rayleigh range reveals a new dynamic system behavior, specifically a return to a stable oscillatory behavior that was not predicted in prior work. Proper Orthogonal Decompositions (POD) using linear interpolation of the solutions to the weakly compressible Navier-Stokes equation has been used to analyze the computational results to extract the details of the fundamental character of the flow. While only five eigenvalue modes were required to capture correctly the basic flow structure, the POD failed to capture subtle aspects of the flow structure at high Rayleigh numbers, indicating that a POD and Galerkin projection for several Rayleigh numbers will be needed to reproduce the complex behavior of the system and to understand its behavior.