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Bifurcation and Stability Analyses in Horizontal Convection

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Horizontal Convection is a flow driven by differential buoyancy forcing across a horizontal surface. It has been considered as a simple model to study the influence of heating and cooling at the ocean surface on the Meridional Overturning Circulation. The mechanisms responsible for transition to turbulence are presented using a bifurcation and global stability analyses of the two-dimensional baseflows. The forcing imposed at the surface creates a circulation characterized by a sinking plume near the pole and an upwelling at the equator. Increasing the magnitude of the forcing, the steady states are shown to undergo a sub-critical bifurcation, leading to a transition in the behaviour of the descending plume These steady states are shown to become unstable to both two and three-dimensional perturbations. The three-dimensional instability modes are characterized by counter-rotating vortices located in the plume and are associated with the Rayleigh-Taylor instability. The two-dimensional instability modes are associated with the vortex shedding of the plume, spreading into the abyss. Using the available potential energy analysis framework, we identify the instability mode responsible for the best mixing efficiency.

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