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Can a simple dynamical system describe the interplay between drag and buoyancy in terrain-induced canopy flows?

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Under non-neutral conditions and in the presence of topography the dynamics of turbulent flow within a canopy is not yet completely understood. This has implications for the measurement of surface-atmosphere exchange by means of eddy-covariance. For example the measurement of carbon dioxide fluxes are strongly influenced if drainage flows happen during night, when the flow within the canopy decouples from the flow aloft. In the present work, we investigate the dynamics of terrain-induced turbulent flow within sloped canopies. We concentrate on the presence of oscillatory behavior in the flow variables in terms of switching of flow regimes by conducting linear stability analysis. We revisit and correct the simplified theory that exists in the literature, which is based on the interplay between the drag force and the buoyancy. We find that the simplified description of this dynamical system cannot exhibit the observed richness of the dynamics. To tackle the full spatiotemporal dynamical system theoretically is beyond the scope of this work, although we can make some qualitative arguments. Additionally, we make use of large-eddy simulation of a three-dimensional hill covered by a homogeneous forest and analyze phase synchronization behavior of the major terms in the momentum budget to explore the turbulent dynamics in more detail.