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The Influence of a Vertical Rotation on the Fluid Dynamics of Compositional Plumes

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Abstract : A compositional plume is a fluid flow in a directional channel of finite width in another fluid of different material composition. The study of the dynamics of compositional plumes plays an essential role in many real-life applications like industrial applications (e.g., iron casting), environmental applications (e.g., salt fingers and sea ice), and geophysical applications (e.g., solidification at the inner core boundary (ICB) of the Earth, and mantle plumes). The dynamics of compositional plumes have been investigated experimentally and theoretically. The experimental works observed that the plume flow seems to be stable, although some experiments showed that it can be unstable. At the same time, the theoretical investigations showed that the plume flow is unstable. This is found to be true even if the plume is subject to rotation or/and in the presence of a magnetic field and even if another plume of different composition is also present. It is noticeable that all the theoretical studies on the dynamics of compositional plumes are conducted in unbounded domains. The present work is to investigate theoretically the influence of vertical walls (boundaries) on the dynamics of compositional plumes in the absence/presence of a rotation field. The mathematical model of the dynamics of compositional plumes used the equations of continuity, motion, heat, concentration of light material, and state. It is found that the presence of boundaries has a strong influence on the basic state solution as well as the stability of the plume, particularly when the plume is close to the boundary, but the compositional plume remains unstable.

Keywords : compositional plumes, stability, bounded domain, vertical boundaries
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