Instabilities in viscosity and density stratified flow

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Summary

Viscosity stratification can create new instabilities in a shear flow, or act to stabilise it. This talk will examine mechanisms of such instabilities, and situations where they can occur. It will also contrast these with instabilities in density-stratified flows, and examine the combination of the two. The aim of this talk is to invite future research on viscosity stratification in the context of the Sun or Earth's interior.

1 Viscosity stratification

Viscosity variations occur in any flow where temperature or concentration is a function of space and time. Viscosity can also be a function of pressure at very high pressure, or a function of shear and its history (non-Newtonian behaviour). Such variations can affect the flow in a profound manner, especially in its stability behaviour, as first shown by Yih [1]. In the Sun, the Earth's core and mantle [2], blood and sugar syrup, viscosity stratifications occur, sometimes viscosity varies by several orders of magnitude.

At high Reynolds numbers, viscous terms appear as a singular perturbation in the linear stability operator of shear flows. Even a small stratification in viscosity, caused for example by variations in composition, temperature or due to the non-Newtonian nature of the fluid, can therefore have a large effect on the stability. This can result in new modes of instability or in large stabilisation. One mechanism for a new instability is when a viscosity-stratified layer overlaps with the critical layer of the dominant disturbance eigenmode.

The talk will first summarise work on instabilities in viscosity stratified flow (mainly from [3] and references therein). This will be followed by an examination of density stratification and how the two kinds of stratification work together. Linear instability, transient growth and behaviour in the regime of nonlinear dynamics will be discussed.

2 Conclusions

A broad indication (with many exceptions) is that flow becomes more unstable as the Reynolds number increases (this is to be expected), as the viscosity in the higher shear region increases, and as the ratio of diffusivities (the Schmidt or Prandtl number) increases.

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References

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