Rotating Stratified Turbulence

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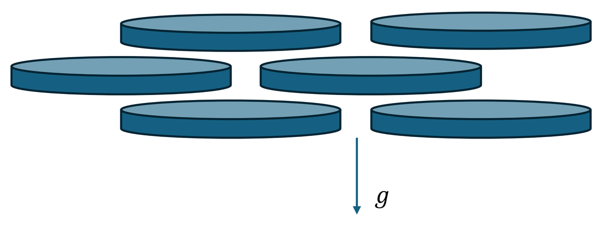
Abstract

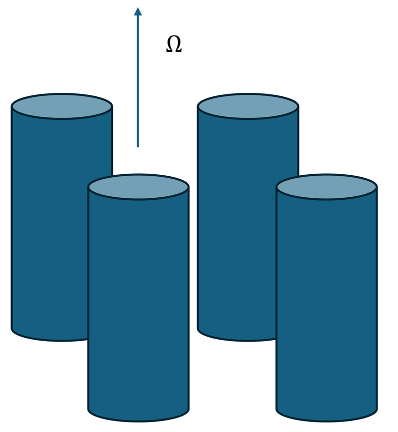
Recent interest in the dynamics of stratified turbulence has led to the development of new models for quantifying vertical transport of momentum and buoyancy (Chini *et al* 2022, Shah *et al* 2024). These models are still incomplete as they do not yet include all of the relevant dynamics often present in real physical settings such as rotation and magnetic fields. Here we expand on prior work by adding rotation. We conduct 3D direct numerical simulations of rotating, stochastically forced, strongly stratified turbulence ($Fr \ll 1$), and vary the Rossby number. We find that rotation gradually suppresses small-scale 3D motions and therefore inhibits vertical transport as Ro decreases towards Fr. The effect is particularly pronounced within the cores of emergent cyclonic vortices. For sufficiently strong rotation, vertical motions are entirely suppressed.

Motivation

Nonrotating stratified turbulence is characterized by strongly anisotropic pancake structures within the flow.



Rotation promotes barotropic structures which are invariant along the axis of rotation.



The Equations

$$
\begin{aligned}
\frac{D\boldsymbol{u}}{Dt} + 2\boldsymbol{\Omega} \times \boldsymbol{u} &= -\frac{1}{\rho}\nabla p + \boldsymbol{F} + \alpha g T \boldsymbol{e}_z + \nu \nabla^2 \boldsymbol{u} \\
\frac{DT}{Dt} + w\frac{d\bar{T}}{dz} &= \kappa \nabla^2 T \\
\nabla \cdot \boldsymbol{u} &= 0
\end{aligned}
$$

Quantitative Results

Qualitative Results

References

Acknowledgements

NSF Grant, masters thesis, and other things