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# Spectral characteristics of turbulence driven by Rayleigh-Taylor instability

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The spectral characteristics of a turbulent flow, such as the flow resulting from Rayleigh-Taylor (RT) instability, can be a useful aid to understanding the fundamental dynamics and energy transfers. In this study, we have investigated the spectral characteristics of RT turbulence in 3D numerical simulations using TURMOIL, a compressible MILES code in which losses of kinetic energy and density fluctuations at the grid scale correspond to a numerical viscosity and diffusivity.

We have studied RT simulations in a domain of size 1×0.8×0.4, with an initially horizontal unstable interface at mid-height, using a grid spacing of $5\times10^{-3}$. The physical properties of the two fluid layers were chosen so that the effects of compressibility were limited. The initial conditions comprised random perturbations to the interface position, of various spectral distributions and amplitudes, sometimes in association with a 2D velocity perturbation representing the removal of a horizontal barrier at the interface in companion laboratory experiments. The evolving spectra of both density and velocity components were calculated, in the horizontal plane at mid-height, up to non-dimensional time $T = t\sqrt{Ag/H} = 10$, where $A$ is the Atwood number, $g$ the acceleration due to gravity and $H$ the domain height.

For most initial conditions, the concentration fluctuations $\overline{c'^2}$ increased across the spectrum up to $T = 1$, with a smooth profile peaking around $k = 50$ and falling off in the dissipation range as $k^{-3}$, while $\overline{w^2} \sim k^{-3.7}$ and $\overline{u^2} \sim \overline{v'^2} \sim k^{-4}$. Between $1<T<5$, while the most energetic scales are smaller than the tank dimensions, mid-wavenumber spectra approach $\overline{c'^2} \sim k^{-1.1}$ and $\overline{w^2} \sim k^{-1.3}$, while spectra in the dissipation range steepen to $k^{-5}$.

A wide range of initial spectra were investigated. The presence of gaps or spikes does not significantly affect the flow, with a smooth spectra attained around $T = 1$ in all cases. Large amplitude perturbations reach this initial spectral shape more quickly, by $T = 0.75$. The simulations with an initial $k^{-3}$ spectrum evolved the most quickly. The 2D perturbation mimicking a laboratory experiment introduced a low wavenumber perturbation (initially around $k = 12$) at about $T = 1$, which also speeded up the flow development.

In this study, the low wavenumber spectra are more sensitive to the initial conditions, and an initial disturbance weighted towards these frequencies evolves more quickly. The high wavenumber spectra and molecular mixing, which occurs at the smallest scales, are less sensitive to the initial conditions.