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Turbulence characteristics of weakly turbulent centrifugal convection

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The onset of small-scale fluctuations around a steady convection pattern in a rotating baroclinic annulus filled with air is investigated using Direct Numerical Simulations (DNS). In previous laboratory experiments of baroclinic waves, such fluctuations have been associated with *Structural Vacillation* which is regarded as the first step in the transition to fully-developed geostrophic turbulence. Here we present an analysis which focusses on the small-scale features.

The model is that of air between two vertical coaxial cylinders of inner radius $a = 34.8\mathrm{mm}$ and outer radius $b = 60.2\mathrm{mm}$, held at constant temperatures, here $T_b = 308\mathrm{K}$ and $T_a = 278\mathrm{K}$, and two horizontal insulating rigid lids separated by a distance d. The cavity rotates around the central axis, here $\Omega = 52\mathrm{rad/s}$. The model equations are solved using a pseudo-spectral collocation-Chebyshev in the radial and vertical, and Fourier method in the azimuthal direction with varying model resolutions, here $108 \times 108 \times 128$. The time integration, based on a combination of Adams-Bashforth and Backward Differentiation Formula schemes is semi-implicit and second order accurate.

This paper focusses on the small-scale structures by an alternative method to filter out the large-scale flow, applied to azimuthal temperature profiles at mid-height and three radial positions, at mid-radius and around 15% from each wall. As the solution was characterised by an almost steady wave drifting along the channel on which small-scale fluctuations were evident, the results could be transformed to a frame moving with the wave structure. From this, the time-averaged spatial structure could be obtained, which could then be subtracted from the standing wave to obtain time series of the residual temperature profiles. The space-time plots of the residuals highlight that small perturbations are emitted fairly regularly (but not periodically) near the warm outer wall from the cold jet which brings cold air towards that wall, and that these perturbations travel, initially fairly rapidly, in the azimuthal direction but then slow down as they approach the hot jet, which originates near this wall and takes fluid towards the inner wall. The case is similar near the cold inner wall with perturbations originating from the incoming hot jet. In the centre of the gap, however, the fluctuations appear to be localised to the jets.

Spatially averaged power spectra from the temperature residuals show a peak corresponding to the emission of the perturbations. At higher frequencies, the spectrum falls off, largely consistent with a f^{-3} law at high frequencies, but with a slight flattening in the frequency range between that of the main perturbation and about 0.1 closer to a $f^{-5/3}$ law.

The spectral evidence suggests that the flow investigated here consists of a fairly steady large-scale convection pattern in the form of three pairs of hot and cold radial jets. From those jets, smaller perturbations are emitted at relatively regular intervals where a jet approaches a wall. The overall flow responds in a cascade of faster (and smaller) fluctuations which appear consistent with two-dimensional, quasi-geostrophic turbulence over a wide range of frequencies similar to results of other DNS studies of geostrophic turbulence.