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DNS of transitions towards Structural Vacillation in an air-filled, rotating, baroclinic annulus

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The transition to disordered behaviour in the form of 'Baroclinic Chaos' provides an important prototypical form of chaotic transition in fluid dynamics. This is of particular geophysical relevance in the context of understanding the origins of chaotic behaviour and limited predictability in the large-scale atmospheres of the Earth and other terrestrial planets. For many years, the differentially-heated, rotating cylindrical annulus has proved a fruitful means of studying the properties of fully-developed, nonlinear forms of baroclinic instability in the laboratory. Laboratory measurements have enabled various aspects of its time-dependent behaviour to be studied under a variety of conditions. The system is well known to exhibit a rich variety of different flow regimes, depending upon the imposed conditions (primarily the temperature contrast ΔT and rotation rate Ω), ranging from steady, axisymmetric circulations through highly symmetric, regular wave flows to fully-developed geostrophic turbulence.

The route to turbulence of baroclinic waves in a rotating, stratified fluid subjected to lateral heating can occur via several possible routes, involving either low-dimensional, quasi-periodic states or via a series of secondary small-scale instabilities.

We consider DNS simulations in an air-filled annulus of transitions to complex forms of Structural Vacillation (SV), which represent the first stages in a route to turbulence via secondary instabilities. Nonlinear wave-wave interactions were found to be an active ingredient in the instabilities of baroclinic waves and bifurcations towards complex and chaotic SV flows.

The transition sequence from a steady wave to a structural vacillation (SV) involved a gradual change in the radial structure of the steady wave as the rotation rate was increased. This was followed by two Hopf-type bifurcations leading to an aperiodic MAV which subsequently gave way to a structural bifurcation which, as yet, could not be classified but showed a significant component of apparently random, or high-dimensional, fluctuations consistent with some previous laboratory findings. This flow appears to be a true precursor to geostrophic turbulence.

References

[1] P.L. Read, P. Maubert, A. Randriamampianina, W.-G. Früh: DNS of transitions towards Structural Vacillation in an air-filled, rotating, baroclinic annulus. Submitted to *J. Fluid Mech.*