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Experiments on transitions of baroclinic waves in a differentially heated rotating annulus with a free surface

Th. von Larcher and C. Egbers

Dept. of Aerodynamics and Fluid Mechanics, Brandenburg University of Technology Cottbus, Siemens-Halske-Ring 14, D-03046 Cottbus, Germany, (e-mail: larcher@las.tu-cottbus.de, http://www.tu-cottbus.de/las)

Baroclinic waves are known to be of particular importance for the transport of heat and momentum in the earths atmosphere and in its oceans. Also atmospheric flows on other terrestrial planets may be affected by baroclinic instability. This phenomenon and its time-dependent conduct has been investigated in laboratory experiments as well as numerically and theoretically since more than four decades. At the beginning of the nineties, methods of nonlinear time series analysis were used to investigate the dynamics of the observed flow states in such experiments [4]. Recent experimental studies focus especially on transitions between different flow regimes [1, 6], on linear stability analysis [2] and also on effects of air as working fluid in contrast to a liquid, i.e. on the effect of viscosity [3, 5].

The leading quantities are the imposed density gradient $\Delta\rho$ and the rotation rate Ω. The viscosity of the working fluid is a further key size. The parameter space is spanned by the dimensionless Taylor number Ta, $Ta \propto \Omega^2$, and the thermal Rossby number Ro, $Ro \propto (\Delta\rho \times \Omega^{-2})$. Generally, three different flow regimes are found: the axisymmetric basic flow regime, steady baroclinic waves and irregular flow. In the first transition zone from axisymmetric basic flow to steady baroclinic waves, both stable and time-dependent flows, i.e. mixed-mode states and different kinds of oscillating flows, are found (cf. [1]). The transition from steady baroclinic waves to irregular flow is smooth, the flow is characterised by structural disturbances of the spacious jet-stream but no further flow states are observed here.

We study experiments of baroclinic waves in a differentially heated rotating cylindrical gap, cooled from within, with a free surface and filled with water as working fluid. The surface flow is observed with visualisation technique. Thermographic measurements give a detailed understanding of the temperature distribution and its time-dependent behaviour. Laser-Doppler-Velocimetry (LDV) technique is used to measure long time series data of the radial velocity component of the flow just below the surface. The time series analysis of the LDV measurements enable us to characterise the underlying dynamics of the flow state.

We present results from two transition zones, first from axisymmetric basic flow to steady baroclinic waves and second to irregular flow. In the first one, steady waves as well as mixed-mode states are found. Here, we do not observe oscillating flows like amplitude vacillating waves. The transition to irregular flow is characterised by an increasing influence of small-scale pattern. The wavy flow of the jet-stream is disturbed and asymmetric structured. Thermographic measurements show the coexistence of the large-scale jet-stream and small-scale vortices. The overall flow is dominated by higher order dynamics. Furthermore, beginning in the region of steady waves, the thermographic measurements show a repetitive separating of relative cold vortices from the inner cylinder.

References

[1] Früh, W.-G. and Read, P. L. [1997] *Wave interactions and the transition to chaos of baroclinic waves in a thermally driven rotating annulus*, Phil. Trans. Roy. Soc. Lond. A, **355**, 101-153

[2] Lewis, G. M. and Nagata, W. [2004] *Linear stability analysis for the differentially heated rotating annulus*, Geophys. Astrophys. Fluid Dyn., **98**, 279-299

[3] Randriamampianina, A., Früh, W.-G., Maubert, P. and Read, P. L. [2004] *DNS of bifurcations to low-dimensional chaos in an air-filled rotating baroclinic annulus*, J. Fluid Mech., submitted

[4] Read, P. L., Bell, M. J., Johnson, D. W. and Small, R. M. [1992] *Quasi-periodic and chaotic flow regimes in a thermally driven, rotating fluid annulus*, J. Fluid Mech., **238**,599-632

[5] Read, P. L., Maubert, P., Randriamampianina, A. and Früh, W.-G. [2004], *DNS of transitions towards structural vacillation in an air-filled, rotating baroclinic annulus*, J. Fluid Mech., submitted

[6] Sitte, B. and Egbers, C. [2000] *Higher order dynamics of baroclinic waves*, Physics of Rotating Fluids, Proc. 11^{th} Int. Couette–Talor Workshop, July 20–23, 1999, Bremen, Germany, Lecture Notes in Physics, **549**, Springer