Simultaneous PIV- and thermography-measurements of blocked flow in a differentially heated rotating annulus

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Keywords: PIV/LDA processing, infrared thermography, baroclinic waves, low-frequency variability

1. Introduction

Already in the fifties, an elegant laboratory experiment had been designed to study baroclinic waves (Hide, 1953). It consists of a cooled inner and heated outer cylinder mounted on a rotating platform, mimicking the heated tropical and cooled polar regions of the earth’s atmosphere.

At the Brandenburg University of Technology (BTU) Cottbus this experiment is conducted as a reference experiment of the DFG priority program 'MetStröm' (Harlander et al. 2009a). Breaking the azimuthal symmetry of the cylinder by mounting a radial barrier that partially blocks the azimuthal flow give rise to new phenomena, not well studied so far (Rayer et al., 1998).

2. Experimental setup

The set-up is shown in Fig. 1. The annulus is described in Harlander et al. (2009a). In contrast to the classical geometry we mounted a barrier in the annulus. Working fluid is deionised water. The experiment can be controlled via the temperature difference between the middle and inner cylinder and the rotation speed of the annulus. The barrier is made of aluminium.

![Fig. 1 Sketch of the experiment. Inner radius a=70mm, outer radius b=120mm, height d=135mm, dT=4K, angular velocity is 4.8 cycles per minute.](image)

3. Results

The flow is observed from above by a PIV and an infrared camera. Thus we are able to capture the surface temperature and the near surface velocity field simultaneously. Fig. 2 shows a snapshot of the temperature and velocity field for an experiment with dT=4K and an annulus angular velocity of 4.8 cycles per minute. Without the blocking, a regular wave with azimuthal wave number 3 would occur. However, due to the barrier an approaching wave crest breaks at the narrowing but recovers about 120° downstream of the barrier (Fig. 2). In the co-rotating coordinate system, this wave propagates pro-grade, i.e. anticlockwise in Fig. 2.

We further computed Fourier spectra for points distributed along a circle located in the centre of the annulus. By using Empirical Orthogonal Function, we were able to isolate the main anomaly patterns from the surface observations.

![Fig. 2 Surface temperature field. Time increases from left to right and from top to bottom. Two full cycles are shows.](image)

4. Conclusion

The asymmetric differentially heated rotating annulus shows interesting transient features. Most notable is the periodic breakdown and strengthening of the system’s dominant wave. By using EOFs we can elegantly separate multiple space- and time-scales governing the annulus flow.

References


R. Hide (1953), Some experiments on thermal convection in a rotating liquid. Q. J. R. Met. Soc., 79, 161


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