Low Prandtl Number Rayleigh-Bénard Convection in a vertical Magnetic Field

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Topic: A.1 Convection and heat transfer in MHD

We are investigating turbulent Rayleigh-Bénard convection in liquid metal under the influence of a vertical magnetic field. Utilizing a combination of thermocouple (TC) and ultrasound-Doppler-velocimetry (UDV) measurements gives us the possibility to directly determine the temperature and velocity field, respectively. Further this gives us the possibility to observe changes in the large-scale flow structure.

By applying magnetic fields to the liquid metal convection, we quantified changes of heat and momentum transport in the liquid metal alloy GaInSn. The experimental results of our setup agree well with theory findings and direct numerical simulations of the dynamics in our convection cell. The requirement of large computing power at these parameters makes it hard to simulate long-term dynamics with time scales from minutes to several hours. Thus to investigate slow developing dynamics like sloshing, rotation, or deformation of the large-scale flow structure model experiments are indispensable.

We demonstrate the suppression of the convective flow by a vertical magnetic field in a cylindrical cell of aspect ratio 1. In this setup Rayleigh numbers up to $6\cdot10^7$ are investigated. The flow structure at low Hartmann numbers is a single roll large scale circulation (LSC). Increasing the Hartmann number leads to a transition from the single-roll LSC into a cell structure. An even stronger magnetic field supresses the flow in the center of the cell completely and expels the flow to the side walls.

Even above the critical Hartmann numbers corresponding to the Chandrasekhar limit for the onset of magnetoconvection in a fluid layer without lateral boundaries we still observe remarkable flows near the side walls. The destabilising effect of the non-conducting side walls was predicted by theory and simulations, and is here for the first time experimentally confirmed.

An additional cylindrical convection cell of aspect ratio 1/2 is set up to extent our researches to higher Rayleigh number up to $5\cdot10^9$. Here we will combine UDV and TC measurements with the contactless inductive flow tomography (CIFT) [1]. With this cell it is possible to determine directly flow velocity and structure in a range of turbulence where, until now, mostly only heat transport measurements exist [2,3,4,5].

References

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