## Direct Numerical Simulation of Magneto-Convection at Low Magnetic Reynolds Number

Jake Ineson (1), Aleksander Dubas (2), Alex Skillen (1)

jake.ineson@postgrad.manchester.ac.uk

University of Manchester (1)

United Kingdom Atomic Energy Authority (UKAEA) (2)

## **Abstract**

Direct numerical simulations (DNS) of Magneto-Convection have been conducted in the Rayleigh-Bénard convection configuration. That is flow between two parallel plates with periodic side boundaries, where the bottom boundary is held at a higher temperature than the top boundary. Resultingly, the initially static fluid is subjected to a temperature gradient and hence buoyancy forces, leading to convective motion. Magnetohydrodynamic effects are introduced by considering the influence of a uniform magnetic field upon the convective system. This work considers both wall-parallel and wall-normal magnetic fields, but only electrically insulating wall boundaries. The present work focuses solely on the inductionless case, with  $Re_m \ll 1$ , meaning induced magnetic fields are negligible. The Rayleigh number is  $10^6$ , the Prandtl number is 0.71 and the Hartmann number is varied between 0 and 80.

The influence of the magnetic field upon the thermal plumes can be seen clearly in figures 1-3, where the flow structures are drastically rearranged depending upon the direction of the applied field. The case with a wall-parallel magnetic (figure 2) becomes quasi-two-dimensional where there is little variation of flow variables along the field direction, and high z-velocity jets form close to the wall. The case with the wall-normal field (figure 3) inhibits the formation of thermal plumes, resulting in thinner plumes lacking in small scale turbulent structures. In this case, as the Hartmann number is increased the system tends towards purely conductive heat transfer until no convective motion occurs at all. This behaviour is analysed using singlepoint turbulent kinetic energy budgets, particular focusing on the Lorentz force term,  $\langle u_i J_i \rangle$ . In the wall-parallel case this is a parabolic profile acting to dissipate the energy produced through buoyancy. Then as the plumes approach the wall, it becomes energetically favourable to convert wall-normal velocity into z-velocity resulting in the observed high-velocity jets near the wall. The wall-normal case has a Lorentz force that peaks close to the wall, acting to inhibit the pressure diffusion mechanism which is responsible for giving the plumes their classic 'mushroom' shape. Again, this explains the thinner plumes observed earlier. This approach is extended to scale space by considering budgets relating second- and third-order structure functions of velocity and temperature, providing insight on how the Lorentz force influences the process of natural convection from a multi-scale perspective.

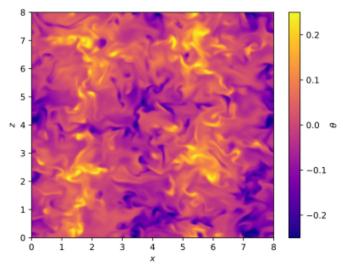


Figure 1: x-z wall-parallel plane plots of instantaneous temperature at the cavity midpoint, with no applied magnetic field.

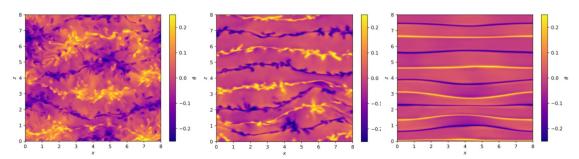


Figure 2: x-z wall-parallel plane plots of instantaneous temperature at the cavity midpoint. (left to right) Ha = 20, 40, 80 respectively. Field in the x-direction.

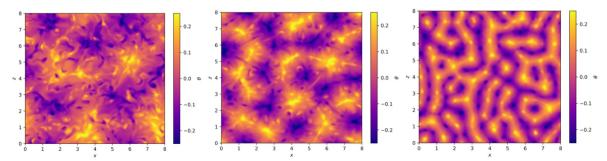


Figure 3: x-z wall-parallel plane plots of instantaneous temperature at the cavity midpoint. (left to right) Ha = 20, 40, 80. Field in the y-direction.