Investigating Schmidt number effects in turbulent electroconvection using one-dimensional turbulence

Marten Klein   Heiko Schmidt

January 4, 2021

We investigate turbulent electrohydrodynamic (EHD) Couette flows of dilute electrolytes and how they are affected by a prescribed electric field. In this canonical problem, molecular diffusion and electric drift currents can interact with turbulence which yields intricate dynamics down to the Kolmogorov and Batchelor scales that need to be resolved. The electrolytes considered have neutral bulk charge and consist of two independent, positive and negative, ion species with the same valence and mobility. The top wall of the set-up is moving and held at a different voltage relative to the bottom one. Resolution requirements and numerical feasibility are addressed by utilizing the stochastic one-dimensional turbulence (ODT) model as stand-alone tool in order to resolve all relevant scales of the flow for a dimensionally reduced setting. Deterministic diffusion and charge-carrier drift are directly resolved, whereas the effects of turbulent advection and pressure fluctuations are modeled by a stochastic process that operates along the wall-normal ODT domain.

For the hydrodynamic and low Schmidt number EHD regime, ODT reasonably captures and extrapolates relevant leading-order boundary-layer properties of reference direct numerical simulations (DNS). For the high Schmidt number EHD regime, the model predicts notable interactions between turbulence and elektrokinetics only for large enough Reynolds numbers that manifests itself by a significant increase of the turbulent drag. Present ODT results suggests that the origin of this effect is related to the time-scale separation of convective versus electric drift and molecular transport processes transport across the boundary layer.

In the talk, we will address the model formulation and its application to EHD Couette flow. Additionally, we will comment on the representation of electrokinetics and hydrodynamics for the selected set-up. Finally, we will discuss the flow regimes in terms of skin friction drag and flow profiles with an eye also on electric variables and time scales.