A fluid model for the study of magnetic islands in a turbulent plasma including neoclassical physics

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Transport in a Tokamak is caused by several mechanisms. While at the plasma edge turbulent transport dominates, neoclassical transport is important in the core region especially for heavy impurities [1]. Furthermore, large-scale MHD instabilities like magnetic islands are known to influence the transport of heat, particles and impurites [2]. It is insufficient to study these mechanisms independently, since the development of a magnetic island may be heavily influenced by small-scale turbulence as well as by neoclassical effects.

Therefore, we want to describe magnetic islands, turbulence and neoclassical physics in one model. We base our work on the 3-field fluid code AMON [3]and extend its underlying physical model. AMON is a parallelised semi-spectral code that can evolve the fluid equations on large grids at reasonable computation times, which permits to study large-scale MHD phenomena and small-scale turbulence in one simulation. Our new model evolves the five fields magnetic flux ψ, vorticity ω, pressure p, density n and parallel velocity $u_{\|}$. This allows for the modelling of tearing modes as well as interchange and ITG turbulence. We model neoclassical physics by introducing an adequate closure relation on the pressure anisotropy, following [4].

Our simulations focus on the situation where the tearing mode is linearly stable and a magnetic island grows due to nonlinear effects. First, we present the generation of a small magnetic island from turbulence and the role of neoclassical physics in the process. We observe that while the initial growth rate of the magnetic island is imposed by the turbulence, its subsequent growth is strongly enhanced by neoclassical physics, leading to neoclassical tearing modes (NTMs). Second, we study the dependence of the saturation size of an NTM on the amount of interchange and ITG turbulence present in our simulation.

Finally, we discuss the potential impact of magnetic islands in interaction with turbulence on transport and the future extension of our model to describe the transport of heavy impurities.

References

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