Fidelity of Model Reduction: Implications of Near Marginality

Lessons learnt from (i) quasilinear, nonlinear gyrokinetic (ii) gradient- & (iii) flux-driven simulations

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Quasilinear (QL) and nonlinear gradient-driven approaches are commonly used to predict turbulent fluxes in the open system made of tokamak plasmas. In this work, their validity is tested against flux-driven turbulent transport in magnetised plasma turbulence, characterized by less simplifying assumptions in the sense that fluctuating and equilibrium – flux-surface averaged – quantities are treated on an equal footing, without any scale separation. QL simulations are performed with QuaLiKiz – both in its standalone local version and in the flux-driven framework [1] – while local gradient-driven turbulent simulations use the gyrokinetic code GKW [2]. These are compared with GYSELA flux-driven turbulent simulations [3].

Two distinct regimes are investigated in ITG (Ion Temperature Gradient) turbulence with Boltzmann electron response: the turbulence is either strongly driven or near-marginal. The distinction comes from the departure with respect to both linear and nonlinear thresholds for turbulence onset. The latter case is reported to feature complex turbulence self-organisation at meso-scales, made of avalanches and zonal flow patterns [4].

It is found that linear predictions regarding phase shifts and amplitude ratio between fluctuating fields, central to the QL framework, retain reasonable validity in turbulent regimes for both cases, although several estimates of the Kubo number yield values around unity. This result is encouraging news for model reduction. Near-marginal regimes however pose another challenge: a significant heat flux is found to be carried below linear stability threshold in flux-driven computations, a property hampered in gradient-driven or QL approaches which postulate scale separation. It results in a significant flux mismatch between modelling frameworks, still present when running flux-driven transport simulations on the basis of QL transport coefficients [5].

Directions whereby to improve reduced models are discussed, possibly through the inclusion of inhomogeneous mixing, turbulence spreading and flow patterning.

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