Questioning the quasilinear nature of turbulent transport by means of gyrokinetic flux-driven nonlinear simulations

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Flux-surface-local quasilinear (QL) theory has proven effective for estimating heat and particle fluxes in tokamaks based on experimental profiles. Meanwhile, full-torus flux-driven simulations reveal new features at intermediate scale, such as avalanches and turbulence self-organisation close to marginal stability[1]. Using the GYSELA code[2], we study the interplay between zonal flows and mesoscale structures and its impact on heat flux. In particular, these results are shown to significantly depart from QL predictions obtained with QuaLiKiz[3], hence questioning the QL nature of fluctuations and their feedback on profiles.

Computed Kubo numbers, ratio of Lagrangian correlation times to the eddy turnover are between unity (mixing length estimate) and a few units. This suggests marginal validity for the QL framework. We feed QuaLiKiz with the time-averaged GYSELA flux-driven profiles. The ratio of QuaLiKiz over GYSELA heat flux ranges from zero to 20. QuaLiKiz values for the phase shift between pressure and potential fluctuations do not match GYSELA's, in contradiction to the assumption that perturbations retain their linear properties in the non-linear regime. The proposed presentation will detail these results as well as highlight the possible role of non-linear features and marginal stability to address such discrepancies.

To this end, the shape and motion of turbulent electric potential structures are computed from the 3D flux-driven field. The inferred motion is mostly toroidal: parallel dynamics compensates poloidal advection, so that the ballooning character of turbulence is preserved. No dynamic deformation of turbulent structures by zonal shear is observed. Computed radial velocities also correlate well with stationary flow shear rates[4,5]. Depending on the zonal flow curvature, turbulent structures can converge towards a zonal flow layer and feature increased turbulent correlation time, or diverge from it and exhibit increased radial correlation length. This asymmetry challenges oft-used prescriptions of shear regulation, and its consequences for transport barrier formation will be discussed.

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