Turbulent transport in tokamak plasmas: bridging theory and experiment

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Understanding and predicting temperature, density and rotation profiles in the confined core of tokamak plasmas requires accurate and rapid turbulent transport codes. Nonlinear gyrokinetic codes allow for detailed understanding of turbulent transport. However, their computational demand precludes their use for predictive profile modelling. An alternative approach is required to bridge the gap between theoretical understanding and prediction of experiments. A quasi-linear gyrokinetic model, QuaLiKiz \cite{1}, allows for a 1 million speedup while retaining key physics. Indeed, in the plasma core, relatively low levels of turbulence are reported, typically below 10\%. Furthermore, by investigating nonlinear simulations it is found that a quasilinear approach is valid \cite{2,3}. It is further shown that the nonlinear phase shift is close to the linear phase shift \cite{2-4} and that the frequency broadening observed in nonlinear simulations typically follows the linear growth rate \cite{3}. Therefore quasilinear gyrokinetic turbulent transport can be used to efficiently model fluxes in integrated modelling platforms. The saturated potential is constructed based on nonlinear simulation results and turbulence measurements \cite{1,2,3}. The predicted particle, heat and angular momentum fluxes have been compared successfully to nonlinear fluxes in a wide range of parameters using the quasilinear gyrokinetic code QuaLiKiz \cite{2,3,5}. In terms of CPU time, a factor one million is gained compared with nonlinear modelling. This allows for extensive interpretative and predictive applications. The computed fluxes are compared to experimental Ni diffusion and convection terms \cite{6}. For heavy impurities such as W, poloidal asymmetries from centrifugal force and anisotropic heating have been implemented \cite{7}. The angular momentum transport coefficients inferred from NBI modulation \cite{8} are shown to be well reproduced by the quasilinear diffusion coefficient and convective velocity \cite{5}. For profile prediction, QuaLiKiz is coupled to the CRONOS integrated modelling code \cite{9}. The density evolution during the transient phase just after the L-H transition in a high current JET pulse is investigated. The slow evolution of the hollow density is well reproduced in the plasma core \cite{10}. This density evolution is particularly interesting because it has been shown to be highly beneficial for access to burning plasma conditions in ITER \cite{11}.

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