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Numerical Diagnostics of Turbulent Transport in Three-Dimensional Magnetic Configurations

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Recent simulations in three-dimensional (3-D) magnetically confined plasmas show various aspects of plasma turbulence, and numerical diagnostics using 3-D simulation data of helical plasmas have been carried out. Here we present results of turbulence analyses (i) in simplified geometry for detailed nonlinear mechanism of heat transport, and (ii) in real 3-D geometry for comprehensive understanding of experimental observations. The former topic is on the case with MHD modes with a rather long wavelength. Global nonlinear simulations of drift-interchange modes in helical plasmas are carried out using a reduced MHD model. The model includes various characteristic time-scales. A 'non-local' effect has been studied in dynamical transport phenomena by the simulation of the heat source modulation. The nonlinear process plays the key role in the response, which takes a finite temporal duration for the energy redistribution. By conditional averaging the characteristic response can be extracted, such as a spiral 2-D pattern of the heat flux, which is formed nonlinearly and sustained for longer duration than the turbulence decorrelation time. An electromagnetic oscillation also exists, which gives the other time-scale. The latter topic is on the case with 3-D equilibrium and shorter wavelength perturbations. Gyrokinetic simulations of Ion-Temperature-Gradient modes in the LHD configuration have been carried out, and the 3-D data obtained from the simulations are analyzed taking into account of the line of sight of the experimental diagnostics. The method to resolve the local spectrum from the integrated signal (2-D Phase Contrast Imaging) is tested using the helical magnetic configuration. A vertical profile of the k spectrum can be obtained from the integrated signal. The analysis routine can give a fluctuation pattern at an arbitrary position, and comparison   with it gives understanding of the observed integrated signals. The extracted component has a peak at a finite wavenumber in this case. A finite width in the local k spectrum deteriorates the spatial resolution. In this way, variety of the numerical diagnostics from several view-points can give physical understanding and quantitative comparison of turbulent plasmas.

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