Real space statistical characterization of turbulence and transport in the TORPEX experiment

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Analysis of turbulent plasma fluctuations is generally done in Fourier space, as the vast majority of the available theoretical models are adopting this framework for practical reasons. However, the assumption of periodicity in time and space that is inherent to Fourier approaches cannot generally be satisfied in non-uniform and bounded plasmas of interest for magnetic fusion. Real-space techniques have thus regained practical importance, both for global numerical simulations of plasma turbulence and the relevant data analysis.

The toroidal plasma experiment TORPEX ($R = 1$ m, $a = 0.2$ m) provides such a global approach to study basic physical phenomena leading to turbulence and anomalous transport. Plasmas are produced by RF waves in the electron cyclotron frequency range in a primarily toroidal magnetic field of 0.1 T. An 86-tip Langmuir probe array covering the whole poloidal section is used to study turbulent structures localized in time and space. A threshold-segmentation approach is adopted to identify the structures, which are then tracked in time using a continuation criterion. Integral geometrical moments are used to define real-space structure observables such as occupied area, integrated excess signal, center of mass, orientation and extension. Structure *events*, such as birth, death, splitting and merging, are recorded along with transport events through surfaces of interest. About 100000 realizations of structures trajectories lasting for up to 500 μs are found to occur during one TORPEX discharge of about 1 s length. A direct characterization of the turbulence in terms of the probability distributions of random variables is obtained from a statistical analysis of the data set. Significantly more information than the average values is extracted in this way, and the excellent reproducibility of the results is demonstrated explicitly. The dependence of the structure-observable distributions upon control parameters such as the magnetic-field pitch angle or the neutral-gas fill pressure is investigated. Macroscopic radial and poloidal transport events are quantitatively measured across the poloidal section and their time-series distributions are analyzed. Correlations with the time dependent profile gradients are investigated. The results are compared with local measurements of transport coefficients obtained by interpreting the plasma response to small sinusoidal perturbations of the RF power in terms of an advection-diffusion model.