Flux tube simulations of plasma turbulence in stellarators and tokamaks typically employ coordinates which are aligned with the magnetic field lines. Anisotropic turbulent fluctuations can be represented in such field-aligned coordinates very efficiently, but the resulting non-trivial boundary conditions involve all three spatial directions, and must be handled with care. The standard “twistand-shift” formulation of the boundary conditions [Beer, Cowley, Hammett Phys. Plasmas 2, 2687 (1995)] was derived assuming axisymmetry and is widely used because it is efficient, as long as the global magnetic shear is not too small. A generalization of this formulation is presented, appropriate for studies of non-axisymmetric, stellarator-symmetric configurations, as well as for axisymmetric configurations with small global shear. The key idea is to replace the “twist” of the standard approach (which accounts only for global shear) with the integrated local shear. This generalization allows one significantly more freedom when choosing the extent of the simulation domain in each direction, without losing the natural efficiency of field-line-following coordinates. It also corrects errors associated with naive application of axisymmetric boundary conditions to non-axisymmetric configurations. Simulations of stellarator turbulence that employ the generalized boundary conditions require much less resolution than simulations that use the (incorrect, axisymmetric) boundary conditions. We also demonstrate the surprising result that (at least in some cases) an easily implemented but manifestly incorrect formulation of the boundary conditions does not change important predicted quantities, such as the turbulent heat flux.
Martin, Landreman, Xanthopoulos, Mandell, Dorland, arXiv:1803.09049 (2018)