A non-twisting flux tube for local gyrokinetic simulations

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Local gyrokinetic simulations use a field-aligned domain that twists due to the magnetic shear of the background magnetic equilibrium [1]. However, if the magnetic shear is strong and/or the domain is long, the twist can become so extreme that it fails to properly resolve the turbulence. In this work, we derive and implement the "non-twisting flux tube" [2], a local simulation domain that remains rectangular at all parallel locations [3]. Convergence and runtime tests indicate that it can calculate the heat flux more efficiently than the conventional flux tube. For one test case, it was 30 times less computationally expensive and we found no case for which it was more expensive. It is most advantageous when the magnetic shear is high and the domain includes at least two regions of turbulent drive (e.g. stellarator simulations [4], pedestal simulations [5, 6], tokamak simulations with several poloidal turns [7]). Additionally, it more accurately models the inboard midplane when the magnetic shear is large. Lastly, we show how the non-twisting flux tube can be generalized to allow further optimization and control of the simulation domain.

References

[1] M.A. Beer, S.C. Cowley, and G.W. Hammett. Field-aligned coordinates for nonlinear simulations of tokamak turbulence. *Phys. Plasmas*, 2(7):2687, 1995.

[2] J. Ball and S. Brunner. A non-twisting flux tube for local gyrokinetic simulations. *Plasma Phys. Control. Fusion*, accepted (arXiv:2012.04785), 2021.

[3] B. Scott. Shifted metric procedure for flux tube treatments of toroidal geometry: Avoiding grid deformation. *Phys. Plasmas*, 8(2):447, 2001.

[4] F. Merz. *Gyrokinetic simulation of multimode plasma turbulence.* PhD thesis, Universität Münster, 2008.

[5] F. Jenko, D. Told, P. Xanthopoulos, F. Merz, and L.D. Horton. Gyrokinetic turbulence under near-separatrix or nonaxisymmetric conditions. *Phys. Plasmas*, 16(5):055901, 2009.

[6] J.F. Parisi, F.I. Parra, C.M. Roach, C. Giroud, W. Dorland, D.R. Hatch, M. Barnes, J.C. Hillesheim, N. Aiba, J. Ball, and P.G. Ivanov. Toroidal and slab ETG instability dominance in the linear spectrum of JET-ILW pedestals. *Nucl. Fusion*, 60(12):126045, 2020.

[7] J. Ball, S. Brunner, and Ajay C.J. Eliminating turbulent self-interaction through the parallel boundary condition in local gyrokinetic simulations. *J. Plasma Phys.*, 86(2):905860207, 2020.