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Full Flux Surface δf-Gyrokinetic Code

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Turbulent transport has long been understood to be the dominant transport mechanism in tokamaks. Stellarators, such as W7X, that have been optimised to reduce collisional (neoclassical) transport are also expected to be limited by turbulent transport [1]. Combined theoretical, computational, and experimental progress has advanced our understanding of turbulence properties and the resultant transport, specifically pertaining to tokamaks. In stellarators, however, the more complicated magnetic geometry gives rise to differences in turbulent behaviour [2]. In particular, the magnetic geometry is no longer replicated along each field line, but instead varies between field lines within a given flux surface in a non-trivial way. This has the consequence that the standard approach of simulating a single flux tube may be insufficient to capture the mechanisms that influence transport; zonal flows that allow for communication across multiple field lines require consideration of the turbulent evolution across an annulus encompassing the entire flux surface.

In order to address this issue computationally, it is necessary to develop an approach to treat the entire flux annulus. We have thus developed a new algorithm to confront this problem and have implemented this into the δf-gyrokinetic code stella that employs a semi-implicit treatment of electron dynamics and retains spectral accuracy in the plane perpendicular to the mean magnetic field. We will describe the new algorithm and show results from its implementation and application to a given stellarator equilibrium. The explicit Full Flux Surface version of stella with adiabatic electrons has been benchmarked against the existing global code GENE, and scans in ρ^* have been performed yielding good agreement with expectation when comparing to flux tube simulations performed with stella. To illustrate the efficacy of the new approach we will then compare the explicit version of stella with kinetic electrons with the equivalent results obtained using the semi-implicit time advance. We present the numerical results obtained thus far, with the aim that such a code can aid future discussions as to the effects of zonal modes in 3D geometries.

[1] Pedersen, T. S., Abramovic, I., Agostinetti, et. al., "Experimental confirmation of efficient island divertor operation and successful neoclassical transport optimization in Wendelstein 7-X. Nuclear Fusion", 62(4), 042022, (2022).
[2] Proll, J. H. E., Mynick, H. E., Xanthopoulos, P., Lazerson, S. A., & Faber, B. J., "TEM turbulence optimisation in stellarators. Plasma Physics and Controlled Fusion", 58(1), 014006, (2015).

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