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Published in:
Proceedings of the 19th Joint EU-US Transport Task Force Meeting

Publication date:
2014

3D Simulations of Plasma Filaments in the Scrape Off Layer

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Abstract

The scrape off layer (SOL) of magnetic confinement devices is inherently turbulent. Both in L- and H-mode, anomalous transport of particles and energy perpendicular to the magnetic field is dominated by the propagation of coherent field aligned filamentary structures. Understanding their dynamics is essential for successful operation of future fusion experiments, as they determine, among other relevant SOL features, SOL widths and particle and heat fluxes to the first wall.

We present results from a newly developed non-linear 3D reduced fluid code for filament and turbulence studies using the BOUT++ framework. Using this code, the motions of isolated filament structures in a local slab geometry have been studied. First, systematic scans were performed, that investigated how the dynamics of a filament is affected by its amplitude, perpendicular size, parallel extent, and the strength of the magnetic curvature that it is subject to. The perpendicular size was found to have a strong influence on the motion of the blob, as it determined the relative importance of polarisation currents to parallel currents in the filament, whilst drift wave turbulence was observed if the initial amplitude of the blob was increased sufficiently.

Next, the 3D simulations were compared to 2D simulations using different parallel closures; namely, the *sheath dissipation* closure [1], and the *vorticity advection* closure [2], which neglects the influence of parallel currents. The vorticity advection closure was found to not replicate the 3D perpendicular dynamics and over estimated the initial radial acceleration of all the filaments studied. In contrast, a more satisfactory comparison with the sheath dissipation closure was obtained, even against 3D filaments with significant parallel gradients, where the closure is no longer valid. Specifically it captured the contracting dynamics of filaments with different perpendicular sizes that were observed in the 3D simulations which the vorticity advection closure failed to replicate. However, neither closure successfully replicated the Boltzmann spinning effects and associated poloidal drift of the blob upwards that was observed in the 3D simulations.

It is concluded that the sheath dissipation closure was more successful in replicating the 3D dynamics, because significant parallel currents closed through the sheath were observed to occur even for ballooned filaments simulations. Nevertheless it is possible that the vorticity closure be may be relevant for situations where the parallel current is inhibited from closing through the sheath due to effects such as strong magnetic shear around X points.

References

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This work was funded by the RCUK Energy Programme [grant number EP/I501045] and by the European Union's Horizon 2020 research and innovation programme. To obtain further information on the data and models underlying this paper please contact PublicationsManager@ccfe.ac.uk. The views and opinions expressed herein do not necessarily reflect those of the European Commission. In addition, this work was carried out also using the Plasma HEC Consortium EPSRC grant number EP/L000237/1 and the HELIOS supercomputer system at Computational Simulation Centre of International Fusion Energy Research Centre (IFERC-CSC), Aomori, Japan, under the Broader Approach collaboration between Euratom and Japan, implemented by Fusion for Energy and JAEA.