Two fluid global simulations of internal and external transport barrier formation and relaxation phenomena in tokamaks

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A two fluid global nonlinear electromagnetic code (CUTIE [1]) evolving the fields on spatial scales ranging from the ion Larmor radius up to the machine size has been used to model internal and external barrier formation and relaxation phenomena in tokamak plasmas. In particular, the formation and relaxation of steep gradients in the temperature and density profiles in plasma conditions as close as possible to those of actual tokamaks (JET and COMPASS-D) is studied. The equations for the electron density, ion parallel momentum, and ion and electron temperature are evolved together with Maxwell's equations for quasi-neutral electromagnetic fluctuations. The equations are written in laboratory coordinates and the geometry is that of a periodic cylinder including toroidal curvature effects in the large aspect ratio limit. The system is initialized with plasma profiles close to those of real experiments (m=0, n=0 component) and a low amplitude uniform spectrum of the turbulent fields (higher m,n components). The profiles of sources (m=0, n=0 component only) are provided consistently with the sources used in the real experiments modelled. The grid resolution allows for study of radial correlation lengths of the order of a few ion Larmor radii. The simultaneous evolution of small scale fluctuations together with mesoscale magnetic structures in the nonlinear phase produces a rich variety of phenomena, including evolution of the radial electric field. We have compared the calculated plasma profiles and global qualitative properties to the experimental measurements. In particular, the formation of internal transport barrier appears to be triggered by low m,n modes near a resonant surface which take energy from the shorter wavelengths and modify the profiles up to the point that strongly sheared rotation arises. We also recover the L-H transition and the ELM related phenomena in COMPASS-D in our simulations as the line-averaged density is varied keeping electron heating power (ECH) constant. A bifurcation is observed between the ELMy and ELM free H mode states.

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[1] A. Thyagaraja *et al*, Phys. Plasmas **12**, 090907 (2005)