Numerical simulations of blob dynamics with finite ion temperature

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Introduction

In this contribution we set out to numerically simulate the turbulent transport in the edge and scrape off layer (SOL) regions on the outboard midplane in a medium sized tokamak such as ASDEX Upgrade or EAST. We study the perpendicular particle and energy transport across the Last Closed Flux Surface (LCFS) using the 2-dimensional numerical model, HESEL[1].

HESEL is energy conserving and based on the Braginskii equations governing the dynamics of a quasi-neutral, simple plasma. It describes interchange-driven, low-frequency turbulence in a plane perpendicular to the magnetic field at the outboard midplane. The model follow the time evolution of 4 fields; the electron density, electron and ion pressures and generalized vorticity. The generalized vorticity, $\omega^* = \nabla^2(\phi - P_i)$, is the manifestation of the polarization current in the model and describes charge separation due to the inertia in the ion response to changes in the $\boldsymbol{E} \times \boldsymbol{B}$ and ion diamagnetic drifts. In the limit of constant ion pressure the model reduces to the ESEL model, which has successfully modeled fluctuations and profiles in JET, MAST, EAST and TCV, see[2]. The HESEL model includes the transition from the confined region to the SOL and the full development of the profiles across the last closed flux surface (LCFS). The model is solved in a local slab geometry with the unit vector $\hat{\boldsymbol{z}}$ along the inhomogeneous toroidal magnetic field.

HESEL is also fully compatible with a scientific workflow engineered by *Code development for integrated modelling* EUROfusion Work Package.

Results

Blob propagation across the SOL due to interchange dynamics on the outboard midplane of a tokamak is studied. Fig. 1 shows a snapshot of blobs being ejected from the edge area into the SOL. During such events particles and energy will be transported very effectively and intermittently far into the SOL. One observes an asymmetry between the temperatures of electrons and ions, a result of difference dissipation rates parallel and perpendicular to the magnetic field lines in the model. Such asymnmetry is in agreement with experimental observations, see e.g.

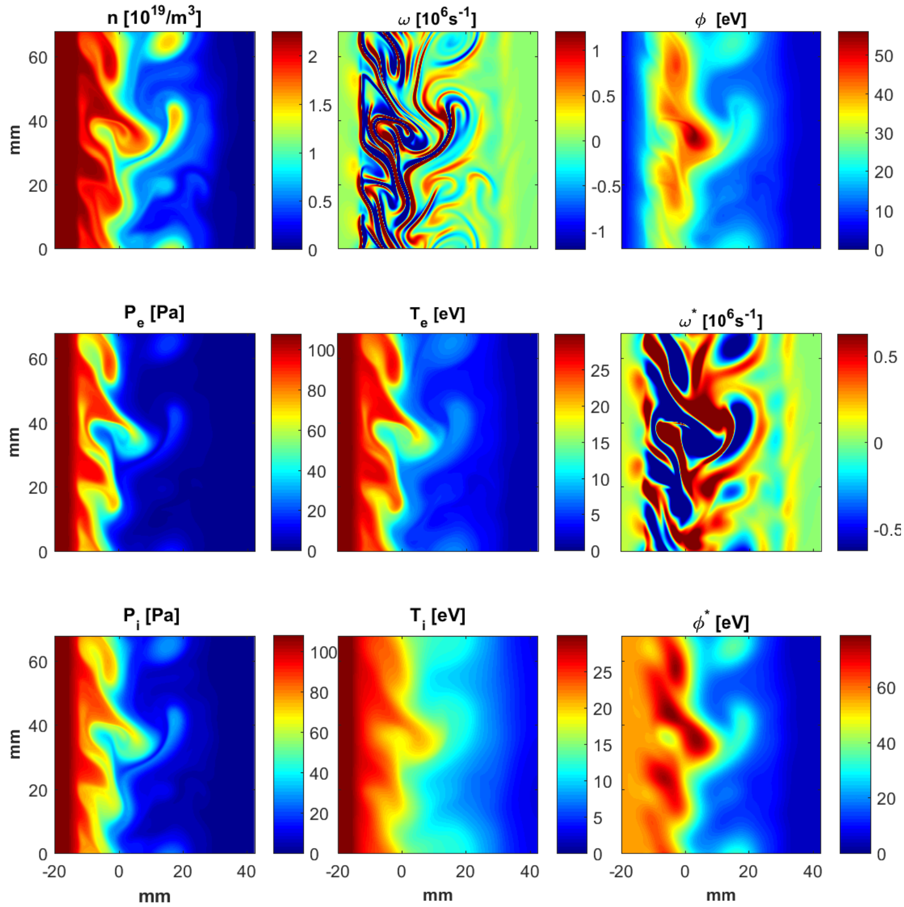

Figure 1: *Snapshot of a HESEL simulation using connected divertor condition: a) density, n, b) electron pressure, p_e, c) ion pressure, p_i, d) vorticity, ω, e) electron temperatures, T_e, f) ion temperature, T_i, g) electric potential, ϕ, h) generalized vorticity, ω^* and i) generalized potential, $\phi^* = \phi - P_i$.*

[3, 4]. Energy losses to plasma facing components, such as the divertor, thus depends heavily on the ion temperature dynamics.

The parallel dynamics in HESEL is parametrized. We assume that transport of plasma across the LCFS is concentrated in a region of 60 degree on the outboard midplane. We thus define a parallel ballooning length; $L_b = qR$ in the parametrisation.

We have implemented the sheath condition in the model - linking the electron potential to the electron temperature in the SOL. This adds a significant sink for the poloidal velocity in the SOL. The sheath term is used to model connected and disconnected divertor conditions[1]. In the connected condition we assume that both the mean and fluctuation part of the potential and electron temperature are coupled by the divertor sheath. Blobs being ejected into the SOL will in this case quickly lose momentum and will be left somewhere in the middle of the SOL where they decay due to parallel loses. Only the connected divertor case is shown in this proceeding.

The inclusion of drift waves in the edge region has shown quite important for the observed

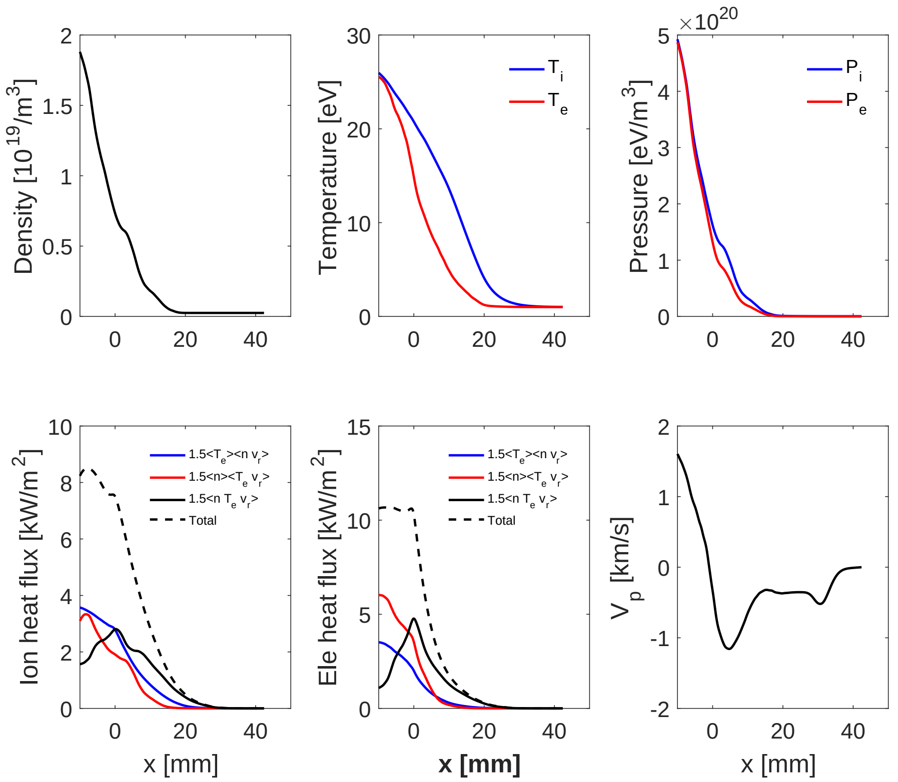

Figure 2: *Radial profiles of density, temperatures, pressures, turbulent perpendicular energy fluxes divided into convecting, conducting, triple product and total flux, and poloidal velocity.*

instabilities in this region. Generally, we do not observed pure drift waves with a phase relation between density and radial velocity close to $\pi/2$ in this region, but the drift wave term controls the length scale of the instability which essentially will determine the size of the blobs being ejected into the SOL. (This model is thus not significantly affected by the choice of aspect ratio of the numerical domain.)

The efficiency of the SOL to remove plasma can be estimated by the ratio of perpendicular to parallel particle transport[5]; $\Lambda = \Gamma_\perp/\Gamma_\parallel = \frac{L_c/c_s}{1/\nu_{ei}}\frac{\omega_i}{\omega_e}$, where L_c is the connection length from midplane to outer divertor leg, c_s is the sound speed, ν_{ei} the electron-ion collision frequency and ω_i and ω_e are the ion and electron gyro frequencies, respectively. In the HESEL model we can change L_c keeping all other parameters constant in the model. We observe a 'shoulder' formation in the density profile for increasing connection length, see Fig. 3 and this is a

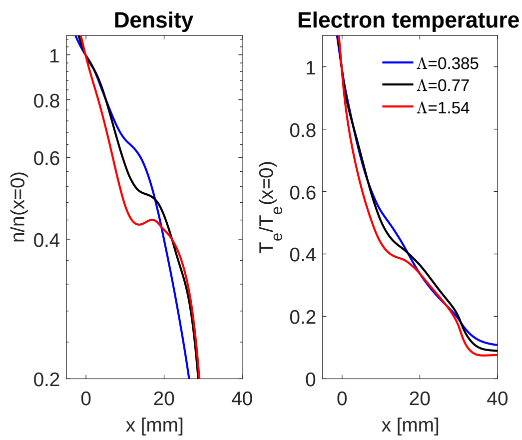

Figure 3: *Radial profiles of density and electron temperature in the SOL for different values of three connection lengths, L_c and thus of Λ.*

result of local processes on the outboard midplane. We are, of course, aware that our parallel physics are simple, but we do notice that our results are in qualitative agreement with experimental observations in COMPASS, AUG and JET, [6, 7] as well with an older comparison between the numerical model, ESEL and Langmuir probe measurements at TCV, see [8, 9].

Finally, we have demonstrated that the energy transport across the SOL, and thus also the energy transport to the divertor region is strongly intermittent and the non-linear triple products in the energy flux terms are dominant. Energy transport is dominated by blob dynamics and we can observe a significant energy transport far into the SOL even in the case of flat density and temperature profiles.

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