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The role of zonal flows in reactive fluid closures

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Abstract

It has been demonstrated[1] that the strength of zonal flows is dramatically larger in reactive fluid closures than in those which involve dissipation due to linear wave particle interactions. This gives a direct connection between the fluid closure and the level of excitation of turbulence since zonal flows are needed to absorb the inverse cascade[2] in quasi 2d turbulence. This also explains the similarity in structure of the transport coefficients in our model, with an exact reactive closure in the energy equation, and models which have an exact reactive closure because of zero ion temperature[2,3]. As a consequence our model is completely self-consistent[1,4-14] and no normalization against nonlinear gyrokinetics is needed. The difference between reactive and dissipative closures first became evident in the Cyclone tests[10] of fluid models against nonlinear kinetic models. The fluid closure enters into the Reynolds stress because of its temperature dependence[1,5,6,7,11,12,14]. In this system we can hardly ever expand in the magnetic drift. This was discussed in terms of a 'New paradigm' in Ref 12. We then get a full transport matrix where particle transport is driven by gradients in temperature as well as density. Thus the temperature dynamics is essential also for particle transport. An interesting aspect is also that resonance broadening has the double effect of removing Landau damping on particle pinches in standard quasilinear models and achieving the fluid closure. An important aspect is also the nonlinear correlation length[8,14].

A detailed discussion will be given on the derivation of the fluid closure[4], giving a an exact closure due to resonance broadening. Our exact reactive closure[4] unifies several well known features of tokamak experiments such as the L-H transition[5], internal transport barriers[6] and the nonlinear Dimits upshift[7,10] of the critical gradient for onset of transport. The fact that kinetic ballooning modes and peeling modes dominate on the H-mode barrier is a choice by the code itself. It is also interesting to note that ITER simulations in H-mode, using this code and including the pedestal, give very similar performance to earlier simulations starting from the top of a pedestal of 4 Kev. This confirms the validity of our reactive fluid model. An overview of consequences and achieved results will be given.

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