Sensitivity of COMPASS tokamak SOLPS-ITER simulations to electron and ion heat flux limiters

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Heat flux limiting, like anomalous diffusion, is a remedy to an intrinsic defficiency of plasma transport codes, here the failure of the classical parallel heat flux formula in low-collisionality plasmas. The classical (or Spitzer-Härm) parallel heat flux density of species a is

$$q_{\parallel a}^{classical} = -\kappa_a \nabla_{\parallel} T_a \tag{1}$$

where κ_a is the parallel thermal conductivity of species a and $\nabla_{\parallel} T_a$ is the parallel gradient of its temperature. Formula (1) was derived under the assumption that the mean free path of species a is much smaller than both the parallel gradient size and the connection length. This assumption, however, is not satisfied in high-temperature, low-collisionality plasmas, and so formula (1) can drastically overestimate the physical parallel heat flux density.

A common practice in transport codes is to limit $q_{\parallel a}^{classical}$ by harmonically averaging it with a fraction of the free-streaming heat flux $q_{FS,a} = 0.8 e n_a T_a v_{th,a}$, where e is the electron electric charge, n_a is the species a particle density and $v_{th,a}$ is its thermal velocity. The free-streaming heat flux is the highest possible heat flux in a plasma. [1] It follows to limit the classical heat flux so it cannot exceed a fraction of the free-streaming heat flux:

$$q_{\parallel a}^{limited} = \left[\left(q_{\parallel a}^{classical} \right)^{-1} + \left(\alpha_a . q_{FS,a} \right)^{-1} \right]^{-1} \tag{2}$$

Here, $\alpha_a \sim 1$ is called the **heat flux limiter**. This is the principle of heat flux limiting.

Although heat flux limiting has been called artificial, *ad-hoc* and arbitrary [2], it can prevent unphysically high parallel heat fluxes in transport codes [1]. Consequently, optimal values of α_e and α_i are of interest. Values between 0.1 and 3 have been suggested [1], the SOLPS-ITER transport code [3] uses $\alpha_e = \alpha_i = 0.15$ by default, and $\alpha_e = \alpha_i = 0.3$ has been proposed for the COMPASS tokamak [4]. Since heat flux limiting can greatly impact the simulation [2], it is strongly recommended to perform a sensitivity analysis before settling on a particular value of α [5]. This contribution presents such a sensitivity analysis, performed by the SOLPS-ITER code in the COMPASS tokamak H-mode discharge #16908.