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Parameter identification for turbulent transport of fusion plasmas

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We consider a κ-ε model for turbulences in fusion plasmas reduced to 1D in the radial direction with self-consistent transport [1]. The evolution of the two fields κ-ε is governed by local dynamics and transverse / parallel transport. The considered model reads:

$$\begin{aligned} \partial_t Z &= \tfrac{D_{gBZ}}{\rho}\nabla_\rho\Big(\rho\tfrac{Z^2}{Y}\nabla_\rho Z\Big) + \gamma_Z Z - KZ^2 - Y, \\ \partial_t Y &= \tfrac{D_{gBY}}{\rho}\nabla_\rho\Big(\rho\tfrac{Z^2}{Y}\nabla_\rho Y\Big) + \gamma_Y Y - \gamma_Z \tfrac{Y^2}{Z^{3/2}}, \end{aligned}$$

where Y and Z are the normalised ε and κ, and ρ the normalised radial position. D_{gB}, the diffusion coefficients, γ, the normalised effective growth rates and K the Kubo coefficient are the reduced parameters determining the behaviour of the system.

For a given set p of such parameters, knowing the target sets of vectors (Z_i^{obj}) and (Y_i^{obj}) corresponding with observation times t_i, we define the following cost function:

$$j(p) = J(Z(p), Y(p)) = \sum_i \frac{1}{2}\Big(||(Z(p))(t_i^{obj}) - Z_i^{obj}||_2^2 + ||(Y(p))(t_i^{obj}) - Y_i^{obj}||_2^2\Big) + \Pi(p),$$

where Π is a regularising penalization term, depending directly on the parameters.

Minimising the cost function j allows us to identify the best parameters p, in the sense that the corresponding trajectory of the normalised $\kappa - \varepsilon$ model is the closest as possible to the target values. The minimisation is performed using a quasi-Newton algorithm [2] and the gradient of the cost function is obtained by automatic differentiation [3].

The identification procedure has been tested on two different cases : spreading with radial variation of the growth rates ratio, and spreading with equal variation of both growth rates and different diffusion coefficients for Z and Y. Parameters are globally very well estimated in both cases.

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