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Extracting data-driven surrogate models from turbulent simulations

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Energy confinement is a key challenge in the development of nuclear fusion reactors, as turbulent transport of heat and particles caused by extreme thermodynamic gradients leads to energy diffusion out of the vessel. As the main parameters that govern this turbulent transport remain elusive to this day, a new data-driven approach aims at developing surrogate models for turbulent transport.

The present work makes use of machine learning algorithms on simulation data obtained with the code TOKAM2D [1,2] that resolves the Hasegawa-Wakatani set of equations [3], i.e. simple low-fidelity model describing drift-wave turbulence in a 2D plane at the edge of the plasma (see Fig 1).
Here, these equations are tweaked to account for the interchange instability, stemming from the plasma curvature in toroidal fusion devices, which adds to the drift-wave turbulence.

Scanning on a wide range of initial background density gradients, these statistical methods result in a model linking the output turbulent flux and Reynolds stress to an arbitrary number of quantities of interest called features (e.g. N-th order spatial derivatives of density and vorticity, turbulent intensity ...).

In a previous work [4], a similar approach led to evidences of 1) a contribution of the vorticity gradient to the turbulent flux acting as a thermodynamical force and 2) the antiviscous nature of the Reynolds stress.
Here, the modifications induced by the symmetry breaking stemming from the interchange instability are discussed.

A special attention is given to the confidence and limits of such data-driven surrogate model, with the intention of setting the stage for more complex and high-dimensional applications.

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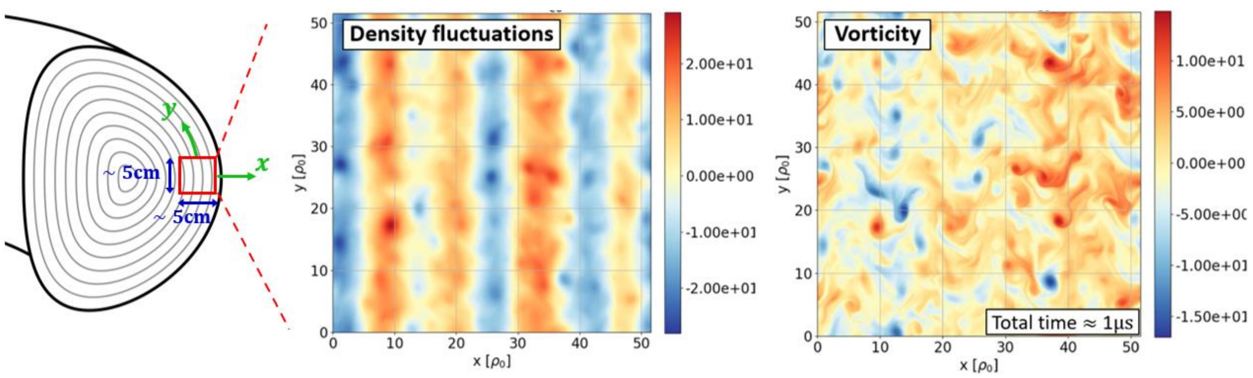

Figure 1 - Overview of TOKAM2D domain and snapshot of density fluctuations and vorticity in a typical simulation