Accurate and easy to implement multi-scale modelling algorithm

The Université Bretagne Sud has developed an algorithm in order to improve fusion plasma simulation (gyrokinetic and kinetic codes, turbulent transport) and especially reached problems of convergence of two-scale models. This project gave the way to transfer information between the various scales while attending simulating a multi-scale phenomenon. Conveniently used to tackle many phenomena involving oscillations or heterogeneities with high degree of accuracy, yet without requiring detailed input, this technology can find many applications in the study of complex fluidics, porous media flow and oscillatory dynamical systems.

Description of the technology

Physical phenomena can be observed and simulated at different scales and degrees of complexity. Multiscale modelling consists in a framework, based on fundamental principles, for building mathematical and computational models of such phenomena, by examining the connection between models at different scales.

The technology consists in an algorithm especially designed to tackle the challenges of convergence of two-scale models widely used for fusion plasma. Tokamak and stellarator are toric devices in which a mixture of deuterium and tritium particles is heated and submitted to a strong magnetic field, in order to ignite a fusion reaction and extract the produced energy. It is well known that the trajectory of a charged particle in a magnetic field is a helix. The period of this helix, called the gyroperiod, depends only on the mass and charge of the particle, and on the magnitude of the magnetic field. As the magnitude of the magnetic field is nearly constant and as there are essentially three species of particles (deuterium, tritium, and electrons), the particle mixture performs oscillations with only a few frequencies, which are well separated from one another. Moreover, since in such devices the magnetic field is strong, those frequencies are high.

Two-scale convergence is efficient but challenging in tokamak or stellarator plasma physics. In addition, the two-scale convergence is the easiest homogenization approach to manipulate and efficiently handle many phenomena involving oscillations or heterogeneities without a lot of analytical material or requiring detailed input.

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Innovation and advantages of the offer

The main benefit of this technology is to transfer information between the various scales while simulating a multi-scale phenomenon. Conveniently used to tackle many phenomena involving oscillations or heterogeneities, it provides effective models in constructive way and without much analytical material. The high degree of accuracy of the approach, yet without requiring detailed input, make it easy to use for homogenization.

Non-fusion Applications

Since multi-scale modeling addresses the different degrees of complexity and scales of physical phenomena, this solution can find many applications in the study of complex fluidics, porous media flow and oscillatory dynamical systems. It has been used for example to model short term dynamics of dunes in tidal area or to forecast the drift of an object in near coastal ocean on a period of several weeks.

EUROfusion Heritage

This work has been conducted in the context of magnetic fusion modeling and simulations under EUROfusion projects : CfP-WP15-ER/IPP-01 and CfP-WP14-ER-01/IPP-03" (Verification of global gyrokinetic codes and development of new algorithms for gyrokinetic and kinetic codes) and CfP-WP14-ER-01/Swiss Confederation-01 (Synergetic numerical-experimental approach to fundamental aspects of turbulent transport in the tokamak edge). The Université Bretagne Sud developed an algorithm in order to improve fusion plasma simulation and especially reached problems of convergence of two-scale models - widely used for fusion plasma and numerical methods to solve them. In particular, this project gave the way to transfer information between the various scales while attending simulating a multi-scale phenomenon. Those works reached a TRL of 4 in fusion.

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