High performance computing challenges in seismic imaging using full waveform inversion

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Full waveform inversion (FWI) is a nonlinear data fitting process for high resolution seismic imaging. It is based on the iterative minimization of the L2-distance between predicted and observed data. The predicted data is computed through the numerical solution of the wave equation in time or frequency domain. The minimization is performed through local optimization techniques based on the gradient of the misfit function and an estimation of its inverse Hessian following quasi-Newton techniques. Compared to standard tomography methods, full waveform inversion is able to yield higher resolution estimates of the subsurface wave velocity. However, as it is based on the repeated computation of the full wavefield, it requires efficient numerical algorithms carefully implemented. In addition, local optimization techniques require a sufficiently accurate initial model to converge to the desired solution. In this presentation, we shall review standard implementation of FWI for industrial scale problems, and present a novel methodology to relax the constraint on the accuracy of the initial model. This methodology is based on the computation of the distance between predicted and observed data using an optimal transport distance. In particular, we will present the properties of this distance in the framework of FWI, and the algorithm we design for its efficient evaluation for large-scale problems.

Numerical modeling of turbulence and transport in the edge plasma of tokamak: a mandatory but challenging tool for ITER

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Particle and heat exhaust physics is one of the main challenges magnetic fusion research will have to solve on its way to full scale reactors. The design of the magnetic configuration and wall shape as well as the tuning of the edge plasma conditions are critical in order to maintain sustainable power fluxes on plasma facing components while insuring an effective pumping of Helium ashes and keeping fusion favorable conditions in the core plasma. The physics at play involves a complex balance between plasma transport processes and volumetric sources and sinks related to atomic and molecular processes occurring between the plasma and recycling or injected neutrals.

Mean-field "transport codes" have been for many years the key tools for the understanding of edge plasma regimes and the design of future machines. These codes rely on models in which plasma turbulence has been smoothed out by averaging and simple closures are used to model the average fluxes and stresses due to fluctuations. In particular, transverse transport is commonly described via a gradient-diffusion hypothesis in which fluxes are driven by local gradients and characterized by ad-hoc diffusion coefficients whose values are determined experimentally. However, these coefficients differ from one machine to another, from one pulse to another in the same device and even from one location to another inside a plasma. They must then be considered as free parameters, which reduces drastically the predictive capabilities of these codes. Fluctuations related non-linearities appearing in atomic physics are not captured either by mean-field models and could influence significantly the results.

In this presentation, I will present the effort led at CEA Cadarache to unlock this bolt. I will specifically introduce the two main edge plasma codes developed by our team, namely SOLEDGE2D and TOKAM3X, and report on the latest advances and results obtained with these two tools. Special focus will be given to numerical challenges still needing to be solved on the way to ITER relevant simulations.