PiAI Seminar Series: Physics informed AI in Plasma Science
10:00-11:00, 15 June 2020 (CEST:UTC+2)
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Web Seminar

Particle laden turbulence: Analysis of clustering using multiscale techniques including tools from machine learning

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The nonlinear dynamics of inertial particles in high Reynolds number turbulence, and in particular particle clustering, are important fundamental processes, e.g. in atmospheric science. Here we analyze particle data from three-dimensional direct numerical simulations of particle-laden homogeneous isotropic turbulence at high Reynolds number, up to Re_λ=531 and with up to 10^9 particles. The influence of Reynolds and Stokes numbers on the multiscale clustering structure is investigated. To this end scale-dependent statistics applying orthogonal wavelet decomposition to the particle density fields are computed. The intermittency of the density fields is quantified by computing scale-dependent flatness values. Negative values of the scale-dependent skewness allow to assess the spatial scale of void regions.

Using Voronoi tessellation of the particle positions, the divergence of the particle velocity can be quantified by determining the volume change rate of the Voronoi cells. We derive theoretically the PDF of the divergence for random particles in random flow. For inertial particles we find that the PDF of the divergence deviates from the theoretical prediction. Joint PDFs of the divergence and the Voronoi cell volume illustrate that the divergence is most prominent in cluster regions and less pronounced in void regions.

Applying tools from machine learning, i.e., the K-means clustering algorithm and the Density-based spatial clustering of applications with noise (DB-SCAN) algorithm we analyze the huge amount of particle data. Different properties of the particle clusters are assessed, e.g. the number of clusters, their size, their densities and the distance between cluster centroids, which are of fundamental importance for developing surrogate models.

Finally, we present first modeling results for particle laden turbulence. Synthetic vorticity fields can be generated using the wavelet scattering transforms and convolutional neural networks. Based on a maximum-entropy principle and using a gradient descent algorithm particle distributions are modeled for different Stokes numbers.

This work is joint work with Thibault Oujia (I2M, Marseille), Keigo Matsuda (JAMSTEC) and Katsunori Yoshimatsu (Nagoya U), Sixing Zhang (IRIT, Toulouse).