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Applications of Persistent Homology to Simulated Turbulent Fluid Flows on a 3D Domain

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We use persistent homology to study two paradigms of complex turbulent fluid flows obtained by direct numerical simulations of the Navier Stokes equations on three-dimensional domains. First, we show how persistent homology can be used in conjunction with diffusion maps to study the properties of vorticity fields of fully-developed turbulence. We use these techniques to uncover a log-linear relationship between existing statistical quantities of vorticity, and also show how these quantities relate to statistics on the persistence diagrams themselves. Second, we use speed profiles in the space of persistence diagrams to study the turbulent combustion simulations of the Homogeneous Charge Compression Ignition process of an n-heptane and air mixture generated by the Tsurushima model, which tracks 35 chemical species across 38 elementary chemical reactions. Our method shows that persistent homology can be used to cluster together chemical species which share common reaction profiles in the low-temperature oxidation phase of the combustion process, as well as point to differences in the reaction process that are caused by different initial turbulence conditions. We compare our methods to the use of speed profiles in L^p space.