Kelvin-Filtered Turbulence and Relation to Space Locality

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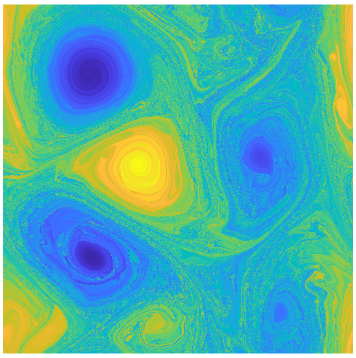
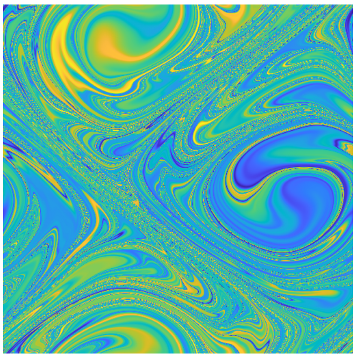
The Kelvin-filtered turbulence models[1] can be understood as a geometric framework for incompressible fluid mechanics describing fluid flow maps from the point of view of Lagrangian mechanics. The approach dates back from the work of Arnold[2]. Choosing the fluid L^2 energy as Lagrangian yields the Euler equations whereas an enstrophy-energy average gives the Euler-α models. The space local or non-local equations[3,4] can also be obtained from this formalism through the definition of a space local or non-local conserved energy. In this presentation, we will present this new geometric perspective on space local and non-local dynamics. The implications of the conserved local/non-local energy on the turbulent energy cascade and its long-time behaviour are assessed in two-dimensional turbulence. In particular, the effect of space-locality on the energy transfer between different scales will be studied in detail and respective modifications to the inertial range spectrum will be presented. A parallel with the Euler-α models will be drawn.

We carry out numerical simulations of the problem using the Characteristic Mapping Methods[5]. These methods are tailored to the Kelvin-filtered models as they directly discretize the inverse flow map which serves as an Eulerian to Lagrangian coordinate transform. A brief overview of the method will be given and high resolution long-time simulations will be presented.



(a) Space-Local Dynamics



(b) Space-Non-Local Dynamics

Figure 1: Comparison of vorticity in freely-decaying 2D turbulence with restricted nonlinearity. Radius of space-locality = 1/4 of domain size.

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