Pre-Registration Form

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Abstract:

Standard diffusive models for Brownian random walks employ the Fickian and Markovian assumptions, which assure locality in space and time. Gaussian statistics appear in solutions for the diffusion equation when the correlation length between particles or fluid elements vanishes. However, the diffusive model does not describe nature in the general sense. The statistics of transport in turbulence with coherent structures are non-Gaussian and poorly described by the standard diffusion equation. In a turbulent fluid or plasma with coherent structures, correlation lengths may be finite. Such coherent structures exist in solutions of the Hasegawa-Mima-Charney (HMC) equation, which is used isomorphically to describe either drift waves in a two-dimensional plasma or Rossby waves in atmospheric Coriolis dynamics.

Turbulent plasmas are commonplace in magnetic confinement devices for producing fusion energy, including the proposed design for ITER (International Tokamak Experimental Reactor). ITER is essentially a scaling-up of smaller tokamak designs, and the scaling of transport with domain size is not well understood. A modified foundation for understanding transport in a turbulent magnetized fluid may depend on so-called fractional diffusion equations (FDEs), which admit superdiffusive and subdiffusive behavior as solutions. Fractional differential equations unify the concepts of nonlocality in space and time with the observations of anomalous scaling by using integro-differential operators.

Evidence is building for the utility of a phenomenological FDE model. Simple Hamiltonian models of the drift/Rossby wave system with coherent vortices produce non-Gaussian statistics and anomalous diffusion. Simulations of pressure-gradient driven plasma turbulence show quantitative agreement between solutions of FDEs and numerical data. It has also been recently reported that a new renormalization scheme for a simple turbulent advection equation leads to fractional operators. Another testing ground for FDEs is the numerical data obtained from a widely used gyrokinetic code for simulating plasma turbulence, called GS2.

Here, we concentrate on using FDEs to describe the transport of passive scalars in the dynamical system created by the HMC model. The streamfunction dictating the transport depends on the equilibrium flow, giving us several cases to compare. The non-Gaussian properties of the transport have already been determined, but ours is the first attempt to use FDEs to describe the statistics. This is a testing ground for more sophisticated studies of the FDE phenomenology.