Onsager symmetries in miscible fluid flow

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Hydrodynamic dispersion at low Reynolds numbers takes place in a wide variety of flows through porous media. Examples include the spreading of contaminants or temperature differences in ground water flow and the spreading of drugs injected intravenously.

In this talk we investigate how Onsagers general theory on reciprocity may be applied to the description of hydrodynamic dispersion. First, we consider the simple case where a source and the point of measurement are interchanged, and prove that the signal remains invariant. Then we look at the coarse-grained description where many pore volumes are averaged and the description is given in terms of a dispersion tensor. In this case Onsager theory may be used to show that this tensor is symmetric. This means that the transport in the direction transverse to the average gradient (the cross-coupling effect) remains the same when the gradient is flipped. In both cases the reciprocity relies on the simultaneous reversal of the hydrodynamic flow field. Finally, we use lattice Boltzmann simulations of some particular flow fields to investigate how these symmetry effects may be applied. In particular, we use the source-receiver symmetry as a means to predict concentrations inside a porous medium that results from external injection, a result that may be relevant in the context of drug delivery.