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Lagrangian Transport Upscaling in Heterogeneous Media

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Effective transport in heterogeneous environments is essentially different from transport in homogeneous media. Spatial medium heterogeneities lead to non-Fickian features such as breakthrough curve tailing and anomalous dispersion. Coarse graining of the microscale transport equations implies the contraction of information. The latter leads to non-Markovian behavior, which can be viewed as the cause of non-Fickian transport features. Using a Lagrangian modeling framework, we discuss transport upscaling and uncertainty in effective Lagrangian and Eulerian models for three different heterogeneity classes: (i) microscale model for media characterized by weakly correlated disorder, (ii) mesoscale model for media characterized by a correlated lognormally distributed hydraulic conductivity and (iii) macroscale model for media characterized by strong Lagrangian velocity correlations. The non-Markovianity of effective transport manifests itself in different ways. In the first case, effective dynamics are described by a continuous time random walk. In the second case, we find a persistent continuous time random walk. In the third case, effective dynamics are summarized by a correlated random walk.