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Statistics of concentration gradients in porous media

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In subsurface environments, concentration gradients develop at interfaces between surface water and groundwater bodies, such as hyporheic zones, saline wedges or recharge areas, as well as around contaminant plumes and fluids injected in subsurface operations. These areas generally represent hotspots of biogeochemical reactions, such as redox, dissolution and precipitation reactions, as concentration gradients create opportunities for reactive agents to mix and generate chemical disequilibrium. While macrodispersion theories predict smooth gradients, decaying in time due to dispersive dissipation, we show that concentration gradients can be broadly distributed since they are enhanced by velocity gradients induced by medium heterogeneity. We thus present a stochastic theory linking the Probability Density Function (PDF) of concentration gradients to flow heterogeneity (Le Borgne et al., 2017). Analytical predictions are validated from high resolution simulations of transport in heterogeneous Darcy fields ranging from small to large permeability variances and low to high Peclet numbers. This modelling framework hence opens new perspectives for quantifying the dynamics of chemical gradient distributions and the kinetics of associated biogeochemical reactions in a stochastic framework.

References:
Le Borgne T., P.D. Huck, M. Dentz and E. Villermaux (2017) Scalar gradients in stirred mixtures and the deconstruction of random fields, J. of Fluid Mech. 812, pp. 578–610. doi: 10.1017/jfm.2016.799