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Precipitation dendrites in turbulent pipe flows

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Surface precipitation in pipelines, as well as freezing in water pipes is of great concern in many industrial applications where scaling phenomena becomes a control problem of pipe-clogging or an efficiency reduction in transport. Flow blockage often occurs even when only a small fraction is deposited non-uniformly on the walls in the form of dendrites. Dendritic patterns are commonly encountered in surface precipitation from supersaturated solutions, e.g. calcite dendrites, as well as in solidification from undercooled liquids, e.g. freezing of water into ice dendrites.

We explore the mathematical similarities between precipitation and freezing processes and, in particular, investigate the effect of fluid flow on the precipitation dendrites on pipe walls. We use a phase field approach to model surface growth coupled with a lattice Boltzmann method that simulates a channel flow at varying Reynolds number. The dendrites orientation and shape depend non-trivially on the ratio between advection and diffusion, i.e. the Peclet number, as well as the Reynolds number. Roughness induced vortices near growing dendrites at high flow rates further affect the branch splitting of dendrites. We show how the transport rate in a pipeline may depend on the different dendritic morphologies, and provide estimates for the flow conditions that correspond to most efficient transport regimes.