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Toward modeling of multi-phase flow patterns using a combination of level sets and one-dimensional turbulence

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From an engineering point of view the flow patterns formed in a pipe carrying two or more immiscible fluids are among the most subtle, scientifically challenging emergent phenomena of classical physics. They are technologically important due to their effects on transport of materials of economic and societal importance, such as oil, gas, coal slurry, and carbon dioxide. For underground sequestration, carbon dioxide is transported at pressures at which several phases can coexist. A very similar physical problem in the geophysical context is the turbulent generation of sea spray which is important for understanding moist and aerosol transport into the lower atmosphere. All these applications are challenging computationally as well as theoretically due to their sensitivity to small scale phase dispersion and resegregation. To maximize the likelihood of successful predictive simulation of such flows, the largest possible range of scales must be resolved, and the parameterization of unresolved scales must be accurate. The key modeling approach used here is One-Dimensional Turbulence (ODT) in which turbulent flow evolution along a notional 1D line of sight is emulated by applying instantaneous maps to represent the effect of individual turbulent eddies on property profiles along the line. Velocity profiles evolve on the line, controlling map occurrences and affected by those occurrences, resulting in self-contained flow evolution that obeys applicable conservation laws. On this line of sight through the multi-phase flow a sequence of phase intervals are represented using level set techniques which prevent the phases from artificially numerical smearing. The surface tension at interfaces stores potential energy and the ODT processes can create, move, and annihilate interfaces. The hybrid ODT level set concept will be outlined in the poster.