Map-based advection, low-dimensional simulation, and superparameterization: tools for cost-effective multiphase geophysical flow simulation

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Simulation in low-dimensional spaces is a widely used technique with diverse applications to atmospheric flow such as 2D simulations of clouds and 2D representations of global circulation. Further reduction to 1D can likewise be useful, but requires a model-based departure from Navier-Stokes flow representation. An approach is described in which turbulent advective motions are represented by 1D instantaneous maps, and illustrative applications are presented. Both 1D and 3D map-based formulations have proven useful in cloud studies ranging from microphysical scales to entrainment scales. Arrays of 1D domains can be coupled to each other and/or to higher-dimensional coarse-grained simulations to create multi-scale flow simulation frameworks that are potentially advantageous for some atmospheric-flow applications. Various possible formulations within this framework are described, and their relationship to the superparameterization approach to general circulation modeling is noted. The capability for affordable simulation encompassing sub-Kolmogorov droplet clustering, droplet collisional and condensational/evaporative growth/shrinkage, and coupling of the latter to cloud entrainment and micro-mixing is highlighted.