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Inhomogeneities and caustics in the sedimentation of marine biogenic particles as passive tracers in incompressible flows

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The sinking of biogenic particles from the marine surface to the bottom is a fundamental process of the biological carbon pump, playing a key role in Earth's carbon cycle. A complete understanding of this problem is still lacking. In particular, it has been recently shown that despite fluid incompressibility, sedimented particles, moving as passive tracers in the ocean, show density inhomogeneities when accumulated on some bottom surface. Here, we analytically derive, in the framework of an initially homogeneous tracer sheet sedimenting towards the bottom surface, the relation between the geometry of the flow and the emerging distribution. From a physical point of view, we identify the two processes that generate inhomogeneities to be the stretching within the sheet, and the projection of the deformed sheet onto the target surface. We point out that an extreme form of inhomogeneity, caustics, can develop for sheets. We exemplify our geometrical results with simulations of tracer advection in a simple kinematic flow.