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Agent-Based and Continuous Models of Locust Hopper Bands: Insights Gained Through the Lens of Dynamical Systems

Locust swarms pose a major threat to agriculture, notably in northern Africa, the Middle East and Australia. In the early stages of aggregation, locusts form hopper bands. These are coordinated groups that march in columnar structures that are often kilometers long and may contain millions of individuals. We report on two models for the formation of locust hopper bands. The first is a two-dimensional agent-based model (ABM) that incorporates intermittent motion, alignment with neighbors, and social attraction/repulsion, all behaviors that have been validated in experiments. Using a particle-in-cell computational method, we simulate swarms of up to a million individuals, which is several orders of magnitude larger than what has previously appeared in the locust modeling literature. We observe hopper bands in this model forming as an instability. Our model also allows homogenization to yield a system of partial integro-differential evolution equations. We identify a bifurcation from a uniform marching state to columnar structures, suggestive of the formation of hopper bands. The second is a one-dimensional ABM that introduces a resource (food) and includes foraging. Here homogenization yields a hyperbolic system of PDEs. Both the ABM and the PDEs manifest pulse solutions which are reflective of field observations. We reflect on the fact that both these models allow reductions that can be analyzed via methods from the study of dynamical system.