CENTER FOR ADVANCED SYSTEMS UNDERSTANDING

CASUS Institute Seminar

Vector-borne disease control on neighborhood-sized spatial scales: A biological application of time-independent perturbation theory

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Date: Tuesday, 22 September 2020

Time: 14:00 – 15:00 CET

Location: CASUS Lecture Room, Görlitz

Abstract:
Tropical diseases spread between humans and mosquitoes pose an ever-increasing threat of world-wide emergence, due in-part to global climate change and our increasingly connected trade and transport networks. Governments typically respond to emerging epidemics the form of integrated vector management strategies targeted at anthropophilic mosquito populations in at-risk residential areas. During the 2016 United States Zika outbreak, management strategies were implemented by conducting intensified aerial spraying and door-to-door control campaigns within neighborhood blocks surrounding residences with a confirmed human transmission. Door-to-door control requires government workers to enter yards to eliminate larval habitats and apply long-lasting barrier pesticides which are highly efficacious, but control is spatially localized and requires residential compliance. Aerial sprays complement the drawbacks of door-to-door control by providing large-scale neighborhood-wide coverage, but aerial sprays are short-lived and can be weakly efficacious.

In this talk, we present a spatially explicit vector-borne disease model which incorporates the complementary nature of door-to-door and aerial spray controls and captures the unique challenges inherent to integrated vector management on neighborhood-sized spatial scales. To assess the effects of vector mobility, percent compliance, and compliance spatial clustering on control efficacy, we analyze our model's basic reproduction number. Curiously, we find the counter-intuitive result that vector mobility is beneficial to disease controllability. To explain this result and understand its implications for real-world control, we delve deeply into the next-generation matrix interpretation of the basic reproduction number, providing analysis and analytic expressions in several limiting but biologically relevant cases. Here, we utilize time-independent perturbation theory techniques typically applied to atomic energy level calculations in quantum mechanics. Interestingly, we find that biological analogs to quantum energy level splitting and symmetry breaking play important roles in understanding the behavior and control of the basic reproduction number.