The Climate Integrated Model of Mosquito-Borne Infectious Disease: A Large-Scale, Mechanistic Approach to Science and Global Forecasting under Climate Change

E.O. Romero-Severson, C. Xu, J. Fair, and C. Manore

Background/Objectives. Mosquito-borne diseases (MBDs) such as malaria, dengue, and West Nile fever are highly sensitive to environmental conditions and are, therefore, likely to show rapid changes in their natural range globally over the coming decades. The difficulty in predicting how the risk of MBDs will evolve is extremely difficult because changing environmental variables affect the biology of both the pathogen and the vector differentially, but also because the physical scale of environmental change is so heterogenous. Even slight changes in wetness and temperature can have differential effects on mosquito population dynamics even in physically proximal regions.

Approach/Activities. Traditional approaches to this problem often take a spatial-statistics approach where large, complex data streams are corelated to known, historical risk profiles to project near future risk of MBDs. A key weakness of this approach is that it doesn't directly incorporate the wealth of prior knowledge that we have from experimental, clinical, observational, and surveillance studies on how changing environmental variables affect the actual biology of vectors and pathogens. Further, advances in remote sensing methods allows us to establish fine-scale characterization of the mosquito habitat potential over very large land masses. The Climate Integrated Model of Mosquito-Borne Infectious Diseases (CIMMID), based on projects from the DOE's Energy Exascale Earth System Model, addresses this gap as a modular, fully-mechanistic modeling framework for both scientific and forecasting studies of MBDs at the global scale. CIMMID uses remote sensing and demographic data to establish Hydrological-Population Units (HUs) as a shared physical scale based on specific mosquito-habitat and human demographic indices. Coupling HUs with mechanistic models of both mosquito lifecycle disease transmission dynamics under different environmental conditions allows us to both calibrate and forecast disease by scaling up from small, ecologically homogenous HUs to broad regions such as counties, states, nations, and larger geopolitical regions.

Results/Lessons Learned. We will discuss the implementation of CIMMID to study the spread of West Nile Virus in the US and Canada using large, heterogenous datasets and the differences between the CIMMID modeling philosophy and machine learning approaches.