Correlations Between West Nile Virus Outbreaks and Meteorological Conditions of the Southern United States

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Project Summary

The World Health Organization and the World Meteorological Organization recently published a report (World Health Organization, 2012) on human health and disease and its relation to climate. Weather and climate play an important role in disease spread, since diseases and their vectors need favorable environments to develop and reproduce. One such disease is the West Nile Virus (WNV). Mosquito vectors of WNV are highly susceptible to weather and climate conditions, but current research in how meteorological parameters influence WNV outbreaks is underdeveloped. Most studies focus on small geographic areas, such as cities or counties. Thus they do not often produce results that apply to whole regions of the United States. This study seeks to understand which and how meteorological characteristics correlate with WNV outbreaks in the Southern Plains, a region of the U.S. largely neglected in past WNV studies. These correlations will be calculated with the intent of producing a predictive index for the Southern Plains. Increased predictability will allow public health officials to better prepare for future outbreaks in an effort to minimize harmful effects.

Research will use meteorological data from the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) as well as from observational networks such as the Oklahoma Mesonet and the Southern Regional Climate Center (SRCC). This data will be correlated with WNV cases reported to the Centers for Disease Control and Prediction (CDC). These correlations will distinguish which factors exert the strongest influence on WNV outbreaks in the Southern U.S. Combinations of the meteorological parameters that correlate well with WNV outbreaks may be used to predict them in the future.

Project Narrative

Introduction & Background

This year (2012) is a record breaking year for West Nile Virus (WNV) across much of the United States. The CDC reports that, as of November 20, there have been nearly 5200 reported cases of WNV so far this year. There is no known reason why the current outbreak is so large (CDC 2012). Nevertheless, many news outlets have reported that the severity of the 2012 WNV outbreak was the result of “unseasonably warm, humid weather . . . followed by spouts of rain that leads to standing water” (Jaslow 2012).

Examination of Figure 1 reveals no strong correlation between the locations of maximum anomalies of soil moisture and temperature and the areas with the highest density of WNV

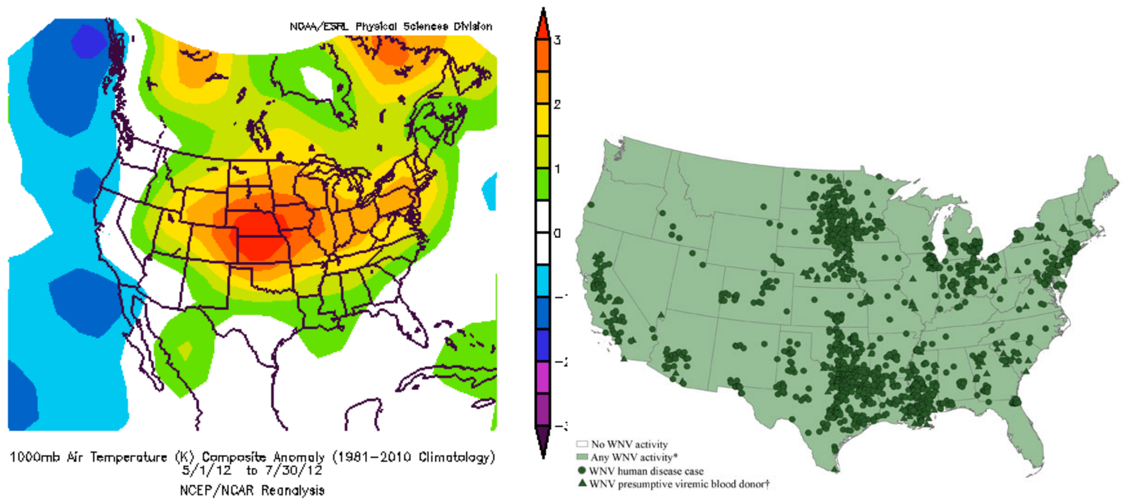

Figure 1a(top): Temperature Anomalies from May 1, 2012 to August 30, 2012 from Earth System Research Laboratory (ESRL). **Figure 1b(bottom):** West Nile Virus activity reported to the CDC. Note that the maximum temperature anomaly is not collocated with the maximum WNV activity.

cases reported and do not support the press' claims, but their suppositions sparked the question that this study seeks to address: Do meteorological conditions contribute to WNV outbreak size and intensity?

West Nile Virus is classified as a flavivirus similar to yellow fever and Dengue fever. WNV can cause meningitis and encephalitis. Although almost 80 percent of those who contract WNV show no symptoms, and most of those in the remaining 20% experience symptoms comparable to influenza (fever, body aches, etc.), severe cases of WNV can cause severe brain damage and paralysis, and WNV is, in some cases, fatal.

Since first being detected in a routine yellow fever check up in Uganda in 1937, WNV has spread across Africa, Eurasia, the Middle East, southern and eastern Europe, India, Indonesia, and then eventually into North and South America (May et al. 2011). WNV made its first appearance in the United States in New York in 1999. Although it is not clear exactly how WNV arrived in the U.S., it is thought that either exotic birds or domestic animals being traded between the Middle East and the U.S. were infected with the virus. WNV is usually carried by birds, but is also known to infect dogs, horses, and other mammals (Artsob et al. 2009). Mosquitos, and in particular, those mosquitos in the genus Culex, are WNV's principal vectors, contracting WNV from these vertebrate hosts and transferring it to other hosts when they feed.

Past studies have attempted to diagnose temperature, rain, and wind correlations to particular West Nile outbreaks across the world. Increased temperature is known to increase rates of mosquito reproduction, shorten the length of the gonotrophic cycle (interval between blood meals) and prolong the breeding season, all of which increase the growth rates of vector populations (Ruiz et al. 2010, Paz and Albersheim 2008). One of these studies based in the Chicago area found that most local outbreaks could be explained through weather conditions, with warmer temperatures explaining the timing of outbreaks, and precipitation patterns (dry spring, followed by a wet period) correlated with the location of WNV outbreaks (Ruiz et al. 2010). The effects of increased temperature are most pronounced on minimum infection rates within a week which goes along with the temperature dependence discussed earlier. The study also found a weak correlation between precipitation rates and minimum infection rates (Ruiz et al. 2010). The years with the highest minimum infection rates correlated with high temperatures and low rainfall 11 weeks prior to the highest minimum infection rate. Looking at rainfall data alone can be misleading as there are other hydrologic parameters that may yield higher correlations with infection rates such as soil moisture or surface relative humidity.

Additional studies have found the similar positive temperature correlations but the correlation varies depending on the maximum temperature. A study in Saginaw county, Michigan found similar results in temperature dependence, but maximum temperatures exceeding 30°C decreased the lifespan of mosquitos. When temperatures rise from 20°C to 40°C, the survival probability decreases from 0.82-0.90 to 0.04. *Culex Pipiens* showed no rainfall correlations early in the season until a negative trend appeared in July (Chuang et al 2012).

Mosquito larvae require standing water and therefore calm winds in order to mature without disruption. Increased wind velocity also suppresses vector mosquito flight, thus decreasing WNV transmission. A study of vector mosquitoes in Sri Lanka concluded that increased wind velocity and maximum temperatures have negative correlations on larval and adult mosquito populations while increased relative humidity has a positive correlation. Like the Saginaw study, the Sri Lankan site reported average maximum temperatures above 30°C (Yasuoka et al 2007). Many studies conducted of WNV outbreaks in the U.S. overlook wind and proper hydrologic data.

Some research into WNV has relied on relating meteorological parameters to mosquito population as estimated from mosquito traps (Hartley, 2012). These traps may produce significant error because the mosquitoes captured may not be a representative sample. Instead, this study will utilize WNV cases reported CDC with the thought that they will prove more reliable for the purposes of determining WNV outbreaks. Furthermore, relating meteorological conditions to populations of mosquitoes trapped limit the ability for this research to apply to a larger, more diverse geographic area. CDC reports will allow comparisons to be conducted over larger areas.

In addition, previous research has focused on the Mid-Atlantic (Jones, 2012), California (Hartley, 2012) and the Northern Plains (Chuang, 2011), but has neglected the Southern U.S., and especially the Southern Plains. Of the reports of WNV this year, one-third of those came from Texas, yet research for this area is scarce. Therefore, this study will focus on the Southern Plains (Texas and Oklahoma), and will seek to gain an understanding of the relationships between WNV and weather.

Objectives

The objectives of this project are as follows:

- Conduct a statistical analysis of WNV incidence and weather conditions for the states of Oklahoma and Texas
- Time permitting, a secondary analysis will include other states in the southern and Gulf Coast regions of the U.S., such as Arkansas, Louisiana, Mississippi, Tennessee, and Alabama
- Find explanations for anomalously large outbreaks of WNV in the South
- Outcomes will be used to derive a predictive index that can match seasonal weather conditions to incidence rates of WNV in the Southern Plains

Ultimately, this project seeks to understand and characterize WNV in the South in relation to weather and climate experienced in the region, and to be able to provide helpful information for preventative measures taken against WNV.

Description of the Project

To accomplish these goals, the authors will statistically analyze relationships between the meteorological signatures and cases of WNV through comparing epidemiological data from the CDC, organized according to date and location, with datasets such as those available through the NARR and more local observational datasets such as the Oklahoma Mesonet and the SRCC. These tools will be used to correlate wind speed and temperature to WNV activity in the region, with the expectation that light winds, and moderately high temperatures will both lead to a higher likelihood of an extreme WNV outbreak. Soil moisture, precipitation, and number of freeze days will also be examined, as some research has suggested that each of these factors may contribute to the spread of WNV.

Broader Impact

If this project is successful, it may lead to the development of a predictive index given statistical correlations of WNV disease incidence and meteorological variables. This index may be used by health organizations to prepare for outbreaks of WNV and to inform decision makers about when to take necessary precautions, such as more aggressive pesticide regiments, to proactively combat WNV. In this way, local governments can save precious monetary resources when WNV activity should be low, also keeping the environment free of unneeded pesticides. Additionally, this increased predictability may allow for health officials to inform the public of an impending outbreak and ask them to take precautions such as avoiding outdoor activities at dusk and dawn when mosquitoes are most active.

Statement of Work

This study can be split into three parts: literature review, data acquisition, and data analysis. Upon completion, results will be summarized in a paper, poster, and an oral presentation. Jack McLean will handle much of the NARR data retrieval, as well as creating plots for the project using python. Charlotte Lunday will retrieve the WNV activity data from the CDC, and acquire additional meteorological data from the Southern Regional Climate Center (SRCC) to confirm our NARR analysis. Jonathan Wille will conduct a thorough review of biological literature. Together, the team will analyze the information learned and hypothesize about possible conclusions. The team will collectively design the poster, give the presentation, and write the final paper, but Jack McLean, Jonathan Wille, and Charlotte Lunday will lead each of these activities respectively.

A timeline of the project is as follows:

- Acquiring Data(January and February): The first step in our research process will be to acquire data from NARR for the determined years relating to temperature, wind magnitude, and soil moisture data from the years will also be obtained from the CDC regarding WNV activity since its arrival in the U.S. in 1999.

- Data analysis (March and early April): The second step of our research process will be to analyze the NARR data and for anomalies and compare these anomalies to WNV active in the researched area.
- Presentation/Paper (late April and early May): Lastly, a poster and presentation will be prepared to summarize the research findings. A written paper will also accompany the project.

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