Infectious Disease and Climate Change: Detecting Contributing Factors and Predicting Future Outbreaks

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ABSTRACT

The spread of infectious diseases worldwide is a cause for concern in areas traditionally susceptible to these diseases and in areas where these diseases have been previously unknown. This work concentrates on diseases for which global infection rates have been increasing and which are transmitted by mobile agents, or vectors. For example, the mosquito is the vector responsible for the transmission of malaria, dengue and viral encephalitis. Identification of the factors, particularly environmental factors which can be detected from satellite imaginary, which are highly correlated to outbreaks of these diseases is an important aspect of this research. Development of a system which will monitor these factors, as well as short term climate variations, such as El Nino events, is also necessary to provide risk assessments for susceptible regions so that intervention strategies may be employed to prevent or limit the impact of many vector-borne diseases. This paper describes a geographical information system that has been populated with climatic, geographic, and disease data used to distinguish correlations between the different data sets. The system provides a graphical user interface that allows for a spatial representation of the number of disease cases to be overlaid on a variety of satellite-derived parameters and geographic data. The Geographical Information System is the tool which, when combined with satellite-derived products, provides a framework for studying disease outbreaks.

I. INTRODUCTION

A vector-borne disease is one transmitted by mobile agents such as a mosquito. For example, the anopheline mosquito carries malaria in many areas of the world, which is one of the greatest health threats in the world. However, mosquitoes are only capable of survival above a given temperature. For example, the Aedes aegypti mosquito dies when the temperature drops below 0°C [1], with most of the larvae dying when the temperature is about 9°C [2]. Therefore, as temperatures vary with short-term climatic anomalies, and as temperatures rise globally due to increase concentrations of greenhouse gases, the mosquitoes are capable of migrating farther poleward, and of surviving at higher elevations [3][4]. This produces a threat of emerging diseases to areas that have been virtually free of those diseases in recent years. The overall warming of a certain area only needs to increase enough to allow for the breeding of the mosquito or other vectors. The increasing drug resistance of diseases and the insecticide resistance of mosquitoes present an increasing threat to many regions of the world, especially when combined with climatic fluctuations [5][6].

The period of time from which the mosquito is infected with a disease such as malaria, until the time the mosquito becomes infectious is known as the incubation period. At warmer temperatures, the incubation period is shorter in length [7]. Shorter incubation periods due to global warming and short-term fluctuations increase the risk of a potential epidemic. For example, the incubation period for type-2 dengue virus is 12 days at 30°C. This period decreases to 7 days when the temperature rises only 2-5°C [8].

The purpose of the studies described by this paper is to evaluate the relationships between the spread of diseases, the characteristics of the vector spreading the disease, and the climatic factors affecting the vector. The model being developed to represent this system consists of several variables, which include climatic, geographic, and mosquito information. Since the system relies heavily on the use of geographic data, a Geographical Information System (GIS) was selected as the primary tool for this analysis. The GIS model being developed here will allow for queries to be made of the database entries, resulting in useful information from which decisions can be made for intervention. The ideal system will have the capabilities of producing accurate results while remaining efficient [9]. The following describes how the data was manipulated and organized to be informative, efficient, and generalized for further enlargements of the project. Note that the current system in development focuses upon the state of Texas. Future work will upgrade the system to cover the entire southern United States.

II. THE SYSTEM

The data selected for the system represents many of the variables affecting the spread of a vector-borne disease, specifically, climatic, elevation, and geographic data. In addition, information on reported cases of disease outbreaks was collected for the state of Texas by the Texas Department of Health and by the Center for Disease Control.

The geographic data provides detailed information about particular locations as well as the elevation of the land. The geographic data contains information on the locations of cities, county boundaries, and the United States border.

The type of climatic data collected was surface temperature and precipitation from the Tiros Operational Vertical Sounder (TOVS - NOAA-series satellite data) for 1985 until 1988. The surface temperature was the average temperature per day for each month covered over 1° by 1° regions. The precipitation was the daily average in millimeters for each month and also covered 1 degree by 1 degree. More extensive daily values at 3-hour intervals will be available soon.

The system uses this data to evaluate relationships between vector-borne diseases and elevation, surface temperature, and precipitation. For example, in Texas the number of cases of malaria is expected to be greater in the warm summer months than in the winter. As expected, June and July are the months with the largest number of cases, while the winter months have the fewest cases. However, heat is not the only factor for mosquito breeding; moisture is also important. Thus, the maximum combination of these, rather than individual maximums, is the key search criteria. Also note that Texas ranges from sea level to over 8200 feet. All reported cases of malaria are located between sea level and 2000 feet, with the vast majority of cases in areas lower than 1000 feet in elevation. The system also highlighted anomalies. Given that mosquitoes do not breed above certain elevations, or below certain temperatures, the system could identify cases of malaria that were most likely not of local origin.

The analysis up to this point has been implemented using graphical overlays, which has supported the initial expectations of the project. Current efforts are concentrating on the development of intelligent search and correlation algorithms. Artificial neural networks, fuzzy logic, and case-based reasoning approaches are being tested. A fuzzy database and query language are most promising. For example, the user may want to view all cases of malaria that lie within a high altitude. The user may not know and, with the fuzzy interface does not need to know, what qualifies as a high elevation for a particular region in order to submit the query to the system [10].

Finally, another large component to this system is a World Wide Web interface. The interface provides access to the GIS and database and presents the user with images displaying the query results. Thus, a user anywhere in the world may ask about cases of malaria reported in Texas in the summer of 1994 that occurred at elevations below 1000 feet and have the results of the query displayed on a map of Texas as well as in numerical form. The web site also provides information about each of the vector-borne diseases and hyperlinks to related web sites. Since some of the data is confidential, access to the disease outbreak information is not yet available to the general public.

III. CONCLUSION

Ultimately, the goal of this research is to provide a means of predicting vector-borne disease outbreaks. Then, the information can be passed on to public health officials and government agencies so preventive action could be taken. While it is unlikely that all the disease outbreaks can be predicted, a system such as this one will be capable of providing a risk assessment of a particular disease occurring in an approximate area. There are many countries that cannot afford to take all the precautionary steps to prevent disease outbreaks. If the country were provided with sufficient information of where and when to take preventive action, the country might be capable of preventing outbreaks from occurring.

IV. REFERENCES

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V. DATA REFERENCES

Ten years (1985 through 1994) of disease data from the Center for Disease Control (CDC) covering the contiguous United States.

Twelve years (1984 through 1995) of disease data from the Texas Department of Health, Infectious Disease Epidemiology and Surveillance Division.

Political boundaries and populated places from United States Geographical Survey (USGS).

A digital elevation model of North America from EROS Data Center.

Surface temperature and precipitation from Tiros Operational Vertical Sounder (TOVS - NOAA - series satellite data.).