A Study of the Environmental Conditions Associated with the 2015 Dengue Outbreak in Southeast Brazil

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ABSTRACT

One of the major carriers of diseases are mosquitos and the diseases they have carried have resulted in epidemics with widespread impact. They are vectors for Malaria, Zika, West Nile and Dengue. An estimated 700 million people worldwide are affected by these diseases. In 2015 there was a Dengue fever outbreak in Brazil. During this outbreak, about 1.5 million cases and 1032 dengue deaths were reported. Since Dengue is carried by the Aedes aegypti mosquito, I have focused my research on the environmental conditions that existed during 2014-2015 in southeast Brazil, specifically in Rio de Janeiro and São Paulo. The data focused on soil moisture, precipitation rates, soil temperature, and land water storage. The measurements were obtained from the data collected by remote sensing Earth Orbiting Systems. I mainly used the Giovanni tool developed by NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) and GLOBE Mosquito Habitat Mapper Data: Georeferenced observations of mosquito habitats and larvae reported by GLOBE students and citizen scientists, to collect and organize the raw land cover data and draw correlations and conclusions from it.

Key Words: GLOBE, Dengue, precipitation rate, Soil moisture, Soil temperature, land water storage

INTRODUCTION

Dengue fever is an extremely dangerous disease. It has been part of both the endemic and epidemic transmission cycles, and while there are few symptoms at first, the end result can vary widely and dangerously, from a mild fever to death by Dengue shock syndrome.

The virus originates from tropical regions of the world although it's effective range is global. It is an acute systemic disease.

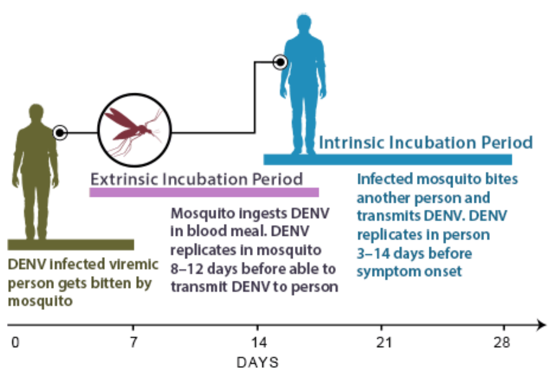

Figure 1: Dengue Virus transmission between humans via mosquitos. Source: www.cdc.gov

As it's tropical origins may imply, the Dengue virus is one of many mosquito-borne diseases. Mosquito-borne diseases are a dangerous, global, and recurring threat that so far have proved to be impossible to eradicate. The Dengue virus in particular is carried by the *Aedes aegypti* mosquito. The expansion of the disease through history has been well-documented, however, the actual distribution and effectiveness of the virus has not, especially in the tropics where it originates. Despite large-scale campaigns to eradicate mosquito-borne diseases, nothing has been effective in the long term, which can mainly be attributed to a lack of information about the spread of these diseases.

HYPOTHESIS

The Dengue virus has been spreading at an alarming rate throughout the world. In 2015, there were about 2.3 million reported Dengue virus cases of which 1.5 million were from Brazil alone.

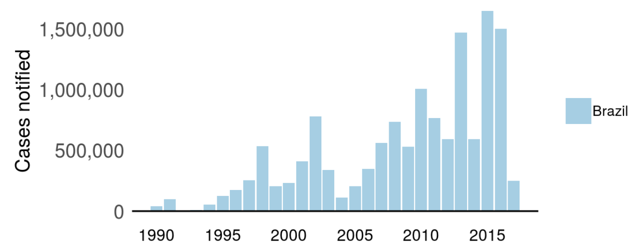

Figure 2: Number of cases for Dengue virus in Brazil from 1990 to 2015
Source: www.who.int

In this study the land cover and environmental conditions that existed around the time of that outbreak has been studied in an effort to understand the correlation between certain types of landcover and environmental data and the mosquito population during the 2015 Dengue outbreak in southeast Brazil.

Figure 3a: Spectral image of lake Jaguari, Brazil in 2014 from Landsat 8

Figure 3b: Spectral image of lake Jaguari, Brazil in 2015 from Landsat 8

PROCEDURE

This study involved collecting a large mass of land cover data and finding a correlation from it. Although the 2015 outbreak was widely spread throughout Brazil, this study focuses on two of the most populated cities - Sao Paulo and Rio de Janeiro.

A large majority of this data was from Earth-observing satellites, such as the Landsat program or TERRA, although a few were conducted on the ground, such as rain gauges. Giovanni (Geospatial Interactive Online Visualization and Analysis Infrastructure), which is developed by NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) and GLOBE Mosquito Habitat Mapper Data: Georeferenced observations of mosquito habitats and larvae reported by GLOBE students and citizen scientists were used as sources of the metadata. The outbreak started around 2014, but it peaked in 2015 and 2016, so that time period was the focus of this study. Different data types have been studied to understand how they impact the Aedes mosquito populations and the Dengue virus.

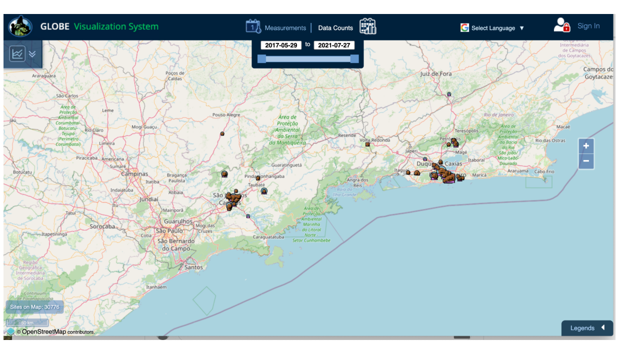

Figure 4: GLOBE Observer Mosquito Mappers reporting observations from Southeast Brazil. Global Learning and Observations to Benefit the Environment (GLOBE) Program, accessed 7/27/2021, globe.gov

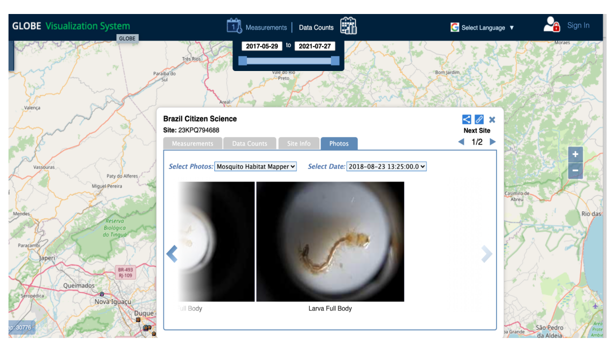

Figure 5: Mosquito larvae image collected using the GLOBE Mosquito Habitat Mapper by Brazil Citizen Scientist.

Four environmental parameters. soil moisture, air temperature, precipitation rate, and land water storage and their influence on mosquito breeding and habitats have been presented in this paper. Data from two major cities in the southeast of Brazil: São Paulo and Rio de Janeiro were tracked. These two cities are densely populated regions of Brazil.

RESULTS AND DISCUSSION

For some background information, there was a drought from 2014 to 2015 in Brazil. Landsat8 spectral images show lakes and other freshwater bodies shrinking significantly in that year. However, it was not a drought related to heat but rather lack of rainfall. However, there was a relatively minimal effect on vegetation. When observing the data, it should be noted that there is a constant cyclical up and down each cycle for about one year.

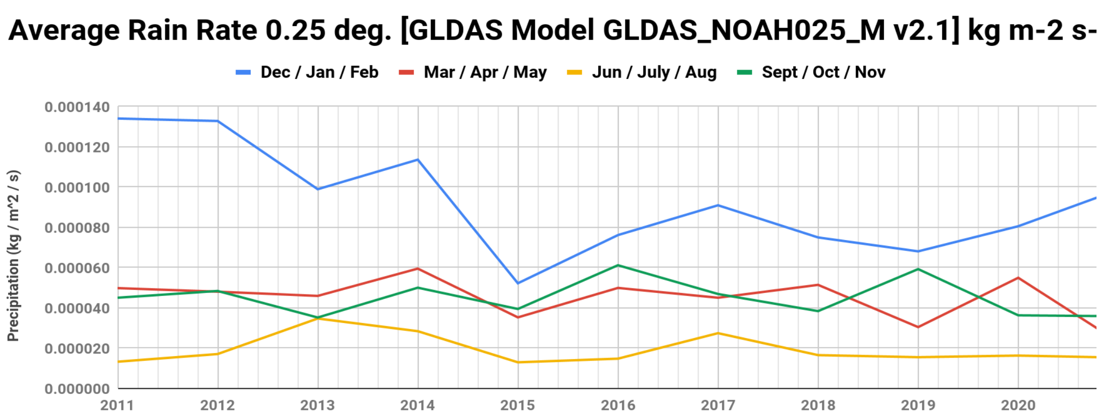

Figure 6: Rate of precipitation in São Paulo and Rio de Janeiro during different seasons.

This pattern can be attributed to change in seasons, and it is present in almost all of the data For the first data type, which was the monthly precipitation rate, there is a noticeable drop around 2014, which stabilizes in 2015, moves up a bit in 2016, and then climbs back to the original pre-2014 height in 2020.

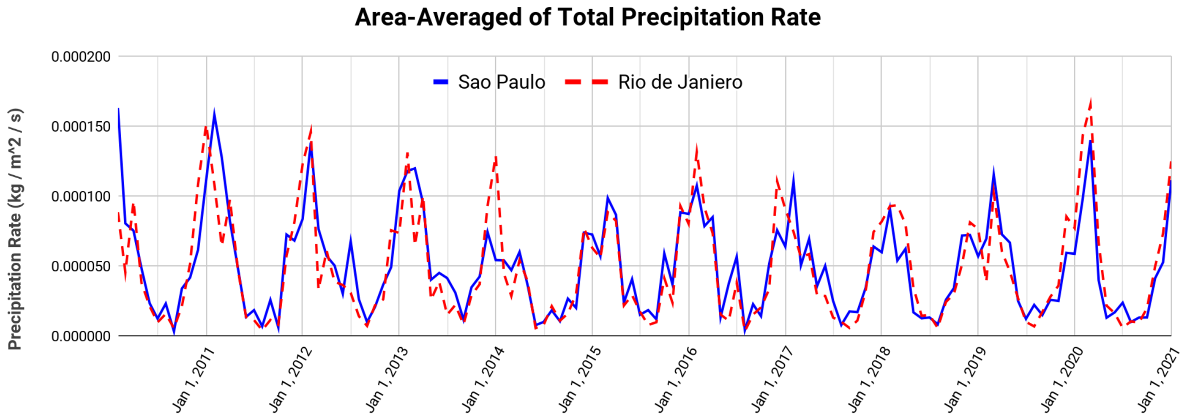

Figure 7: Average precipitation rate for Sao Paulo and Rio de Janeiro between 2010-2021

In other words, while there was a serious drought in 2015, the years following were also a bit lacking in rain, while not being a full-on drought. When there is a shortage of rainfall, first there is no new water to feed the lakes and rivers, and secondly, these bodies of water begin to noticeably dry up, the first happening much more immediately than the second. If there is nothing feeding the bodies of water, they do not move, and become stagnant water. It takes a while until the water actually evaporates and decreases in size, so in the meantime, there will be a large amount of stagnant water. Literature reviews on mosquitos have shown that mosquitoes favor stagnant water over following water.

The second environmental factor that was studied was soil moisture. Soil moisture is predominantly used by plants. Researching the drought, showed that the groundwater in the southeast region of Brazil was being depleted especially because the cause of this drought was lack of rainfall rather than excessive heat.

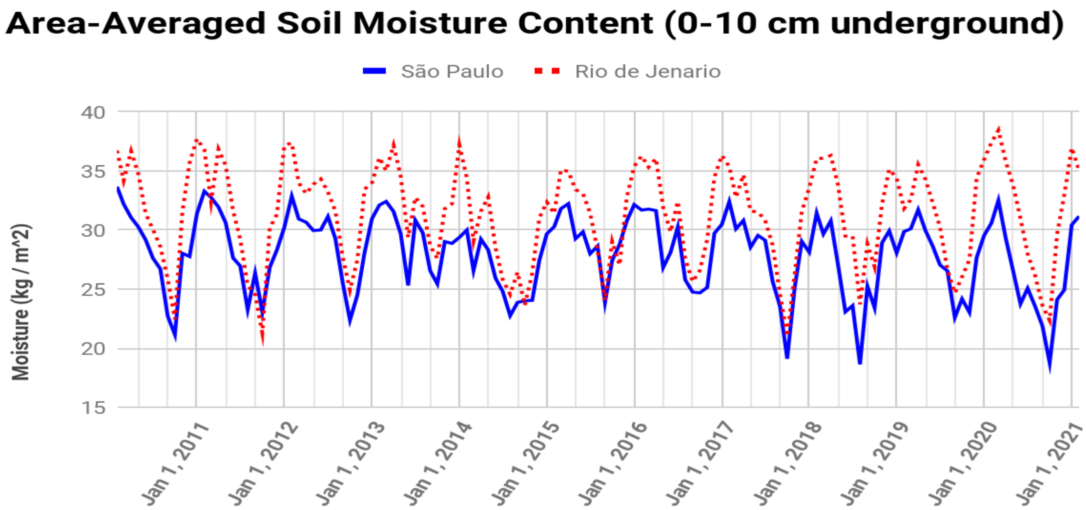

Figure 8: Soil moisture in Sao Paulo and Rio de Janeiro between 2010-2021.

Another thing mosquitos like in their nests in addition to stagnant water is shade. Besides the certain types of rock formations, the terrain on the Earth does not reliably provide shade, and manmade structures do not change their distribution due to the weather. This makes vegetation and plant life the only other form of shade. The graph shows a minimal impact upon the soil moisture, meaning that despite a drought, the mosquitos had adequate shade to breed.

The third parameter is the ambient temperature of the air. Mosquitos have variable incubation periods dependent on the temperature. So long as the temperature is below 20˚C, the incubation takes about 20 days. However, the higher you get from 20˚C, the faster the mosquitos mature and after 30˚C the mosquitoes survival rate diminishes,

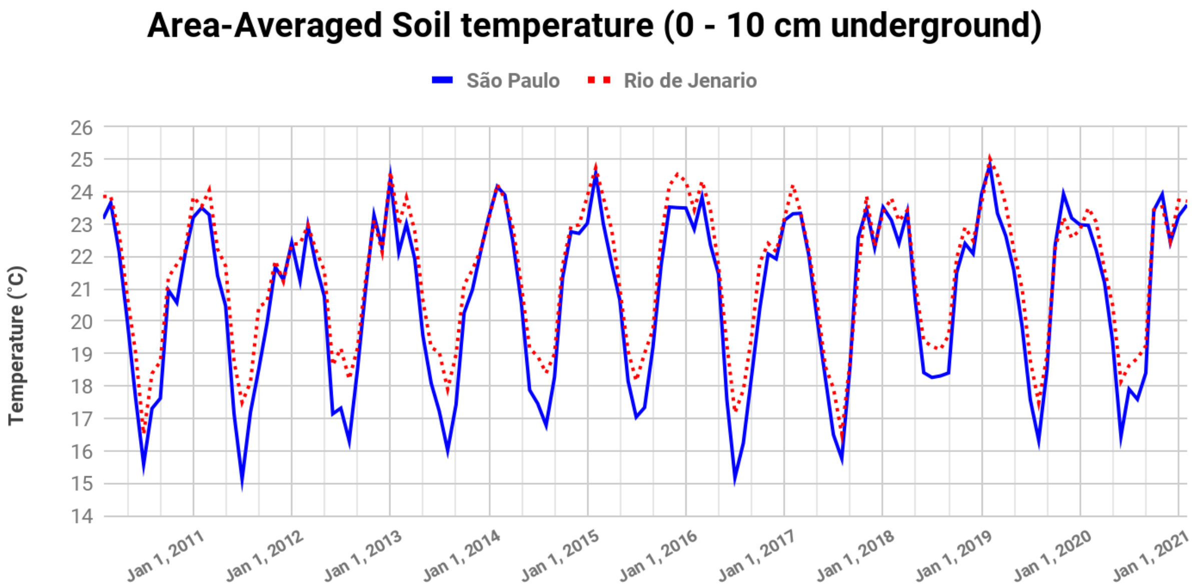

Figure 9: Soil temperature in Sao Paulo and Rio de Janeiro between 2010-2021.

The ambient air temperature data, when represented on a graph, shows a slow but constant and steady upward trend. Interestingly, this trend actually plateaus during the 2015 Dengue outbreak, then continued upward afterwards. However, the temperature was already at around 23˚C the entire time. It is possible that this may have actually helped the prosperity of mosquitos, because it removed the need for larvae to try to adapt to a constantly changing temperature as they grew up, which would have otherwise brought many complications into the maturing of those mosquitos.

Lastly, land water storage data was examined. Land water storage represents the amount of water stored above or on the surface of the Earth, whether naturally (like a lake) or artificially (like a water tank). Just like precipitation this statistic dipped down significantly during the drought and the simultaneous outbreak in 2015.

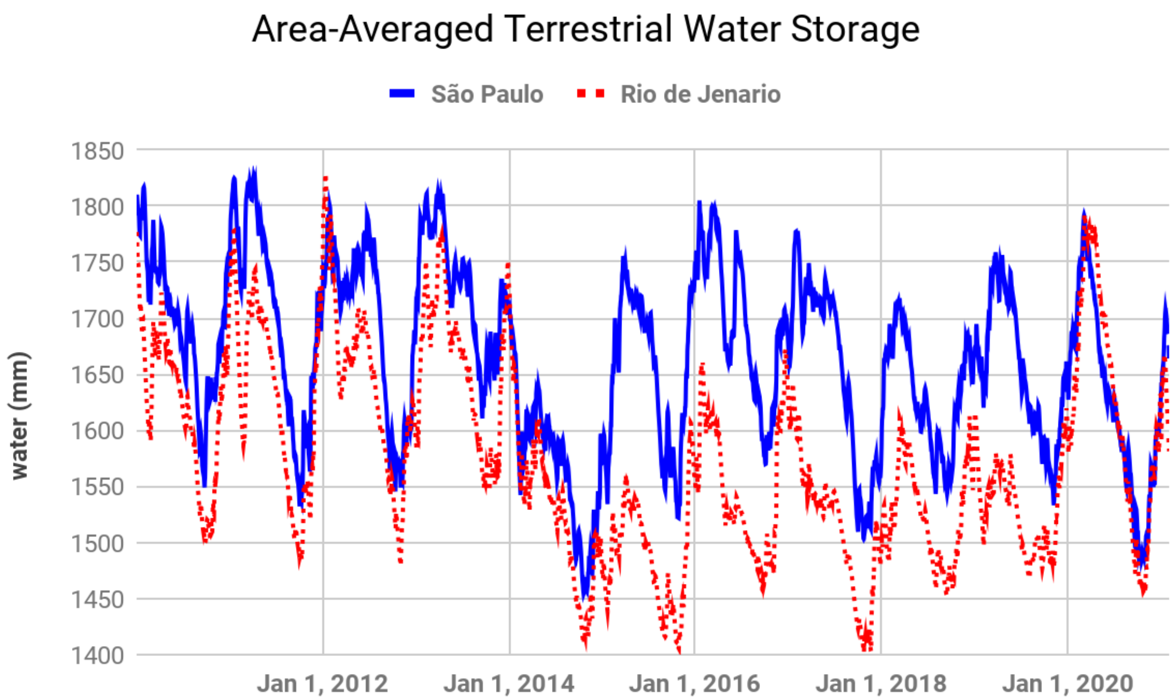

Figure 10: Land water storage in Sao Paulo and Rio de Janeiro between 2010-2021

However, unlike precipitation, land water storage recovered back to its original status by 2016. I think this backs up the conclusion from the first data type, because while the amount of water went back to normal, most of it was probably still stagnant. Mosquitos may like stagnant water, but what they love is even more stagnant water.

CONCLUSION

In conclusion, the environmental conditions that could lead to a vector borne illness can be studied using Earth Observing Satellites and Citizen Science data. This will facilitate deployment of appropriate procedures to mitigate another such outbreak in a timely manner.

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GLOBE Badges

- **Be a Data Scientist**

This project relied heavily on data collected by remote sensing earth observing systems. The data was not readily available in the form I needed it, so I had to sort through and analyze that data to understand it.

- **Make an Impact**

The project is about finding what impacted Brazil to cause such a Dengue outbreak as the one in 2015 By finding that cause, I can make a good impact next time there is a similar outbreak.

- **Be a STEM Professional**

I worked with my SEES Mentors a lot, in particular Dr Podest and Dr Low, in order to come up with and organize this project. They are credited

- **Be a STEM Storyteller**

I was able to connect the different aspects of my project by telling them as a narrative rather than as a procedure with data.