**NASA DEVELOP National Program**

**Spring 2016 Project Proposal**

**NASA Ames Research Center**

**Puerto Rico Health and Air Quality II**

Utilizing NASA Satellite Imagery to Analyze the Effects of Climate Variability on Dengue Cases in Puerto Rico

**Project Overview**

***Objective:*** To assess the effects of environmental variables related to the presence of the dengue virus in Puerto Rico. Additionally, to derive and statistically evaluate these variables to produce a Vulnerability Index Method with the goal of complementing early warning systems for dengue and vector-based diseases in Puerto Rico.

***Community Concern:*** The dengue virus is the fastest-growing vector-borne disease in the world and has been declared endemic to the tropics. This deleterious illness is transmitted by mosquitoes and, when contracted, can lead to fever, vomiting, and death in severe cases. In Puerto Rico, approximately 26,776 suspected cases and 12,000 incidences were recorded in 2010, one of the warmest and wettest years in the Caribbean in over a century. Although the number of cases compared to the Island’s population (3.5 million) might seem small (less than 1%), the health authorities in the Island have a great concern, particularly due to their limited resources. Furthermore, these cases include local people as well as tourists.

There is strong evidence supporting the relationship between climate change, environmental conditions, mosquito vector populations, as well as dengue incidence and transmission particularly in Puerto Rico (Johansson et al. 2009a) and other tropical areas (Johansson et al 2009b). For instance within the San Juan Metropolitan Area, it is expected that with elevating sea levels, the boundaries of the San Juan Bay estuary will expand, posing a threat to coastal communities. Further, the correlation between sea surface temperature, increased abundance of salinity-tolerant mosquitoes, and higher dengue transmission in coastal zones (Ramasamy and Surendran 2011, 2012) supports the hypothesis that Puerto Rico may experience higher rates of dengue as sea level rises.

***National Application Areas Addressed:*** Health & Air Quality, Climate, Weather

***Study Location:*** Puerto Rico

***Study Period:*** January 2009 – December 2013

***Advisor:*** Dr. Juan Torres-Perez (Bay Area Environmental Research Institute)

***Source of Project Idea:*** Project partner Dr. Pablo Mendez-Lazaro, who has done previous studies of climatic variability and its relation to dengue outbreaks, approached Dr. Juan Torres-Perez about this project.

**Partner Overview**

***Partner Organizations:***

Puerto Rico Department of Health (End-user, POC: Jessica Cabrera, Director, Oficina de Preparación de Coordinación de Respuesta en Salud Pública – BioSeguridad.

U.S. Centers for Disease Control and Prevention (CDC) Dengue Branch (End-user, POC: Dr. Roberto Barrera, Chief of Entomology and Ecology at the CDC Dengue Branch).

Medical Sciences Campus of the University of Puerto Rico (Boundary Organization, POC: Pablo Mendez-Lazaro, Assistant Professor in the Department of Environmental Health)

***End-User Current Decision Making Process:***Currently, the various entities involved in this project use quantitative research on vector-borne diseases and outbreaks such as dengue to inform public policy on vector control measures that can be taken to prevent the spread of such illnesses.

Puerto Rico’s Department of Health creates reports on recent statistics and information regarding mosquito vector habitats, and publishes scientific publications related to various illnesses in Puerto Rico. Typically, at the start of the rainy season in PR, the Department of Health begins a campaign in the local media to orient the public on best practices to avoid the development of mosquito larvae within their premises.

The Dengue Branch of the U.S. Centers for Disease Control and Prevention (CDC) is the only CDC branch dedicated solely to dengue research, and it is located in Puerto Rico.

***NASA Earth Observations Capacity:***

Puerto Rico’s Department of Health is familiar with NASA Earth observations, but has not used any Earth observations for their research. This project will introduce the Department of Health to the application of NASA Earth observations in predicting potential areas of future dengue and related vector-borne disease outbreaks. The Department of Health will directly use the products of this project to identify areas in danger of dengue virus transmission and enhance their warning system to the public.

The Dengue Branch of the U.S. CDC is familiar with NASA Earth observations, but has not used any Earth observations for their research or reports. The use of NASA Earth observations in this project will provide the CDC Dengue Branch with a time series of past outbreaks and projected hazard areas to support their monthly surveillance reports that are disseminated to the public.

***Collaborator & Boundary Organization Support:***

The Medical Sciences Campus of the University of Puerto Rico: Pablo Mendez-Lazaro (POC) and the Department of Environmental Health will support this project by disseminating the methods and results of this project to the Puerto Rico Department of Health, U.S. Centers for Disease Control and Prevention (CDC) Dengue Branch. The Medical Sciences of the University of Puerto Rico has strong connections and relationships with hospitals across Puerto Rico and will serve as a conduit to disseminate the product of this project to hospitals and medical institutions.

***Communication Plan & Transition Approach:***

During the first term, the DEVELOP team established a strong foundation of communication with Dr. Pablo Mendez-Lazaro, Jessica Cabrera, and Roberto Barerra through telecons and email. In the second term, the team will continue having 1-2 telecons per month with project partners to communicate the progress of the project. At the end of the second term, the team will hold a virtual hand-off where they will walk through a compiled package consisting of the time series of past dengue outbreaks (2006-2011), the Vulnerability Index Method (VIM) tutorial, and a manual detailing how to download data and use the VIM.

***End-User Benefit:***

The Puerto Rico Department of Health provides citizen services, public announcements, and conducts health assessments pertaining to dengue awareness on the island. This project will assist this agency in informing the general public in Puerto Rico about the health risks of dengue, and how to avoid contracting this disease. The Dengue Branch of the CDC employs public health practices such as education on the household spread of dengue, installation of surveillance systems for dengue-infected hospitals, and diagnostic testing. The tools from this project will directly serve to support these public warnings and educational services. Any results and statistics generated from this project would directly benefit this branch in its data collection and public outreach campaigns. As such, the CDC Dengue Branch will use the VIM to help create monthly reports and public service announcements to inform the public, and policy measures to prevent the transmission of dengue.

Additionally, assessing the risk of dengue virus will contribute to Dr. Mendez-Lazaro’s research that focuses on the effects of climatic variability on the presence of dengue in San Juan, providing a greater scope of vector vulnerability across the island of Puerto Rico. As Jessica Cabrera (Department of Health) detailed in her letter of support: “We are certain that the students have a great opportunity to develop skills … to take into effect an efficient tool to monitor variables that can influence the dengue cases that have been markedly reported in Puerto Rico.”

**Letters of Support:** Puerto Rico Department of Health, Jessica Cabrera, Carta Dr. Pablo Mendez Lazaro.pdf.

**Earth Observations Overview**

***Earth Observations:***

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| **Platform** | **Sensor** | **Geophysical Parameter** |
| **Aqua** | MODIS | Sea surface temperature, land surface temperature, evapotranspiration, sea level, drought |
| **Suomi NPP** | VIIRS | Sea surface temperature, land surface temperature |
| **Landsat 5, 8** | TM  | Shoreline changes |
| **TRMM** | PR | Precipitation |
| **GPM** | DPR | Precipitation |

***NASA Earth Observations Use:***

MODIS data (sea and land surface temperature, evapotranspiration and sea level) will be obtained and used to establish correlations between these parameters and the occurrence of potential sites for mosquito development in the coastal regions surrounding Puerto Rico. These variables have been correlated to predictable habitats for the mosquito vector carrying the dengue virus.

Similarly, data from VIIRS on sea and land surface temperature will be correlated with sites of confirmed Dengue cases in the Island. These data will be combined with the MODIS data (see above) for a more robust predictive model.

Landsat 5 and 8 data will be used to study shoreline changes in Puerto Rico over the past decade. With the higher spatial resolution of these sensors (30 m), we aim to track changes coastal features such as wetlands. The results will be correlated with the physical parameters data from MODIS and VIIRS.

GPM, which have recently been launched, will provide state-of-the-art hydrologic measurements to aid in the understanding of habitat suitability for mosquito vector larvae. The larvae flourish in standing water, and warming sea temperatures appear to influence larvae development. MODIS, TRMM, and VIIRS will be utilized to derive a Vulnerability Index Method (VIM) of dengue on the island using parameters related to sea surface temperature, land surface temperature, evapotranspiration, and mean sea level. Additionally MODIS Global Terrestrial Drought Severity Index (GTDSI) products may help assist in better understanding the recent major drying period in Puerto Rico and its potential effects on dengue cases.

***Ancillary Datasets:***

Dengue fever cases in Puerto Rico - Dengue Branch of the Centers for Disease Control and Prevention (CDC) and the Puerto Rico Department of Public Health (PRDH) Passive Dengue Surveillance System (PDSS); Dengue fever cases in San Juan-*in situ* datasets provided by Dr. Pablo Mendez-Lazaro; Downscaled soil moisture, ambient temperature, runoff, rainfall, humidity, soil saturation, and wind speed – University of Puerto Rico-Hydroclimate Data Download Center; Total precipitation – Climate Hazard Group InfraRed Precipitation with Stations (CHIRPS); Relative humidity – Geostationary Operational Environmental Satellite system Puerto Rico Water Energy Balance (GOES-PRWEB); Land cover – 2011 National Land Cover Database; Projected temperature and precipitation- Coupled Model Intercomparison Project Phase 5 (CMIP 5); Elevation data – NOAA Puerto Rico, PR 1 arc-second MHW DEM.

**Decision Support Tool & End-Product Overview**

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| **Proposed End Products** | **Decision Impacting** | **Current Partner Tool/Method** |
| Vulnerability Index Method (VIM) | Show potential areas where environmental conditions for the development and spread of dengue is favorable in Puerto Rico according to environmental factors for potential early detection of dengue. This will assist the Department of Health and CDC Dengue Branch in assessing which communities may require the most disease prevention resources and training. | *in situ* data |
| Time Series of Past Outbreaks  | Consider the relationship between environmental variables and reported cases, with respect to dengue outbreaks that have occurred in Puerto Rico. This provides historical context to the dengue outbreak and will allow the Department of Health and CDC to analyze whether these regions should continue to be of greater concern. | N/A |
| Statistical Results from the Indices  | Provide a better understanding of the significance each environmental variable contributes to dengue. This will assist the Department of Health and CDC in prescribing varying preventative health measures to Puerto Ricans based on ecological residency.  | N/A |
| Vulnerability Index Method (VIM)Tutorial | Allows end users the ability to recreate results using NASA Earth observations and for future research opportunities.  | N/A |

*Vulnerability Index Method* (VIM)– The VIM will serve as a tool to identify which areas of Puerto Rico are most at risk of the dengue vector, providing early detection of this disease, as well as other vector-borne diseases on the island. It will incorporate rainfall, land surface temperature, sea surface temperature, evapotranspiration, and mean sea level data. There is potential to incorporate additional variables, such as soil moisture, humidity, soil saturation, and wind speed when updated dengue case data become available. Ultimately, the VIM will provide our end-users with spatial, statistical, and tutorial products.

*The following components are a part of the VIM:*

*Time Series of Past Outbreaks* – The time series allows a visualization of historical dengue outbreaks within Puerto Rico and San Juan. This product will be useful for providing policy makers and the public with a better understanding of the potential localities and severity of dengue from a historical context. The time series will be a set of GIS layers showcasing the results from the VIM.

*Statistical Results from the Index* – We will use maximum entropy species distribution techniques to (1) delineate the statistical significance between dengue cases and climatic variables of interest, (2) assess the statistical significance of these trends over time, and (3) investigate the relationship of these trends to recent major outbreak events. These results will quantitatively assess environmental factors contributing to dengue cases from a geospatial perspective.

*Vulnerability Index Method (VIM) Tutorial* – This tutorial will outline our project methods and allow end-users without prior experience in remote sensing to create updated and more refined results when improved data are available.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2015 Fall to 2016 Spring

***Multi-Term Objectives:***

* **Term 1** – This term focused on the city of San Juan and developed methods to derive a VIM to incorporate rainfall, land surface temperature, sea surface temperature (SST), evapotranspiration, mean sea level data, and their statistical contributions to reported dengue cases from 2009-2013. The team downloaded and gathered all necessary data, began to model and analyze the potential correlation of dengue cases in San Juan with environmental variables of interest, and laid the ground work for the second stage of analysis.
* **Term 2 (Proposed Term)** – The Spring 2016 term will focus on analyzing the results from the maximum entropy modeling approach and better understanding the trends contributing to major dengue outbreaks within the whole Island of Puerto Rico from 2009-2013 as a means to identify variables that may contribute to future outbreak events. The team will further explore additional variables in the model, including soil moisture, wind speed, ambient temperature, and evapotranspiration. The team will focus on refining their analyses and investigating variables with a strong correlation, including the relationship between SST and TP lag times, as well as CDFC to TP lag times. Moreover, the team will examine the results from the first term and narrow their study area within the island of Puerto Rico. An end-user tutorial will also be developed for utilizing and updating the Vulnerability Index Method.

***Previous Related DEVELOP Work:***

Fall 2015 (ARC) – Puerto Rico Health and Air Quality: Utilizing NASA Satellite Imagery to Analyze the Effects of Climate Variability on Dengue Cases in Puerto Rico

Summer 2015 (GSFC) – Alto Orinoco Health and Air Quality: Utilizing NASA Earth Observation to Locate Yanomami Villages in the Alto Orinoco Municipality for Targeted Eradication of River Blindness Disease

Fall 2013 and Spring 2014 (JPL) - Brazil Health and Air Quality: Utilizing NASA Earth Observations for Forecasting Dengue Virus Outbreaks

Spring, Summer, and Fall 2014 (IRI) - East African Health and Air Quality: Using NASA Earth Observations as a Tool to Evaluate the Relationship between Rainfall Extreme Events and Inundation in East Africa to Understand Epidemic Dynamics

Fall 2014 (IRI) - Zanzibar Health and Air Quality: Creating a Land Cover Map Using NASA Earth Observations to Identify Locations of Malaria Transmission in Zanzibar

Spring 2014 (MCHD) – Alabama Health and Air Quality: Habitat Suitability Modeling of Triatoma sanguisuga, the Expected Local Vector for Chagas Disease in the South Eastern United States

Spring 2011 (MCHD) - Alabama Health and Air Quality: Vector Borne Diseases Risk Mapping

**Project Needs/Requests**

***Participants Requested:*** 3

***Software & Scripting:***

* ArcGIS - Raster Manipulation/Analysis, Image Enhancement & Map Creation of Landsat OLI, NPP VIIRS, Aqua/Terra MODIS
* TerrSet IDRISI- Ecological Modeling, Image Processing and Interpretation

**Notes & References:**

***Notes:*** A team at the Medical Sciences Campus of the University of Puerto Rico, led by Pablo Mendez-Lazaro, has assessed the effects of climatic variability on the incidence of dengue in San Juan using the NOAA Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Sea Surface Temperature (SST) product for coastal regions of Puerto Rico. His team derived 13 of the 27 indices recommended by the International Expert Team on Climate Change Detection and Indices (ETCCDI), all of which pertain to temperature and rainfall. They then utilized the Principal Correlation Analysis, Pearson correlation coefficient, and Mann-Kendall trend test and logistical regressions to determine possible relationships between the climatic variables of interest, and to assess the significance of the time series trends. Their results demonstrate that the spread of this virus can proliferate when sea surface temperature and minimum air surface temperature increase, and when there is an increase in the number of consecutive wet days in the region. These climatic variables can provide a suitable environment for mosquito vector breeding grounds and larvae habitats. A paper published by Dr. Mendez-Lazaro et al. (2014), titled *Assessing Climate Variability Effects on Dengue Incidence in San Juan, Puerto Rico*, states, “Additional research is needed to help understand patterns in other municipalities of Puerto Rico, and in other tropical islands and mainland locations.” This project intends to accomplish these needs by emulating the methodology described in the aforementioned paper.

***References:***

Johansson MA, Dominici F, and Glass GE. 2009a. Local and global effects of climate on dengue transmission in Puerto Rico. PLoS Negl Trop Dis. 3(2): e382.

Johansson MA, Cummings DA, and Glass GE. 2009b. Multiyear climate variability and dengue – El Niño southern oscillation, weather, and dengue incidence in Puerto Rico, Mexico and Thailand: A longitudinal data analysis. PLoS Medicine. 6(11): 1262.

Méndez-Lázaro P, Müller-Karger FE, Otis D, McCarthy MJ, and Peña-Orellana M. 2014. Assessing climate variability effects on dengue incidence in San Juan, Puerto Rico. Int. J. Environ. Res. Public Health. 11: 9409-9428.

Ramasamy R and Surendran SN. 2011. Possible impact of rising sea levels on vector-borne infectious diseases. BMC Infectious Diseases. 11(1): 18.

Ramasamy R and Surendran SN. 2012. Global climate change and its potential impact on disease transmission by salinity-tolerant mosquito vectors in coastal zones. Frontiers in Physiology. 3.