# NASA DEVELOP National Program
## Fall 2015 Project Proposal
NASA Ames Research Center

## Puerto Rico Health and Air Quality
Utilizing NASA Satellite Imagery to Analyze the Effects of Climate Variability on Dengue Presence in Puerto Rico

### Objective:
To assess the effects of climatic variations related to the presence of the dengue virus in Puerto Rico and derive and statistically evaluate variations to produce a Vulnerability Index to complement 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 in the Caribbean and Puerto Rico. This deleterious illness is transmitted by tropical mosquitoes and, if contracted, can lead to fever, headaches, nausea, rash, and vomiting. These symptoms may lead to hemorrhagic fever, shock, and even death in severe cases, posing a major threat to the health of Caribbean communities. Chikungunya is another virus transmitted by *Aedes* spp. that can be difficult to distinguish clinically from dengue. Both are emerging infectious diseases in the region and render similar symptoms. An epidemiological analysis of these vector-borne diseases is necessary for the island of Puerto Rico.

Research on this topic has been conducted in Puerto Rico's capital, San Juan (Méndez-Lázaro et al., 2014). A high occurrence of mosquitoes (primarily *Aedes* spp.), known vectors of the dengue virus, has been detected in this city. Several dengue outbreaks have recently been recorded in Puerto Rico, including instances in 1994, 1998, 2007, and 2010. Considered a Pan American outbreak, this virus affected over 12,000 people in Puerto Rico in 2010, which was recorded as one of the warmest and wettest years in the Caribbean in over a century. There were 40 confirmed fatalities during this outbreak.

Additionally, due to elevating sea levels, the San Juan Bay estuary boundaries are shifting toward the coast of Puerto Rico; this suggests that there is a higher chance of the dengue virus affecting the island, as there is a strong correlation between mean sea level, dengue, and mosquito vector populations. Further, there is an apparent correlation between Sea Surface Temperature (SST) and an increase in the dengue transmission as salinity-tolerant mosquitoes become more abundant in the coastal zones of other tropical countries (Ramasamy and Surendran 2011, 2012); thus, this evidence supports the hypothesis that Puerto Rico may experience higher rates of the dengue virus as sea levels rise.

### End-Users/Partners/Boundary Organizations:
Medical Sciences Campus of the University of Puerto Rico (Boundary Organization, POC: Pablo Mendez-Lazaro, Assistant Professor in the Department of Environmental Health)
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).

Dr. Juan Torres-Perez, along with the DEVELOP Ames leadership, has been in communication with Dr. Pablo Mendez-Lazaro regarding this potential project. The project timeline is to begin in the fall of 2015 and carry on through the spring of 2016. During the second term, there is

potential for an MSc or PhD candidate from the University of Puerto Rico to join the current project team and conduct research at the DEVELOP office at the Ames Research Center.

Assessing the risk of dengue virus on all parts of the island of Puerto Rico will complement the research that Dr. Mendez-Lazaro has been conducting over the past several years. As his studies focus on the effects of climatic variability on the presence of dengue in San Juan, this project will provide a greater scope of vector vulnerability in all of Puerto Rico.

After emulating the methods that Dr. Mendez-Lazaro has utilized in his study of San Juan, DEVELOP will provide end-results to various governmental organizations located in Puerto Rico, such as the Department of Health and the Dengue Branch of the U.S. Centers for Disease Control and Prevention.

**Letters of Support:** Letter of support is provided in Spanish by Puerto Rico Department of Health end-user Jessica Cabrera.

## 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. The Department of Health provides citizen services, public announcements, and conducts health assessments pertaining to dengue awareness on the island. The Dengue Branch of the CDC employs public health practices such as education of household spread of dengue, surveillance systems of dengue-infected hospitals, and diagnostic testing. They also conduct molecular research and field investigations regarding dengue contraction and control.

Dr. Mendez-Lazaro and his team have processed AVHRR products to analyze environmental variables contributing to the proliferation of dengue in San Juan, Puerto Rico.

Puerto Rico's Department of Health reports on recent statistics and information regarding mosquito vector habitats, and publishes scientific publications related to various illness in Puerto Rico. This project could assist this agency in informing the general public of Puerto Rico about the health risks of dengue, and how to avoid contracting this disease.

Additionally, the Dengue Branch of the U.S. Centers for Disease Control and Prevention is the only CDC branch dedicated solely to dengue research, and it is located in Puerto Rico. Any results and statistics generated from this project would directly benefit this branch in its data collection and public outreach campaigns.

## Earth Observations:

| Platform | Sensor | Geophysical Parameter |
|---|---|---|
| **Terra** | MODIS | Sea surface temperature, land surface temperature |
| **NOAA-7** | AVHRR | Sea surface temperature |
| **Suomi NPP** | VIIRS | Sea surface temperature, land surface temperature |
| **GEOS-5** | MERRA | Wind speed |
| **GPM** | DPR | Rainfall |

**NASA Earth Observations to be Highlighted:**
Each satellite listed above assists in obtaining rainfall, air surface temperature, sea surface temperature, sea level pressure, wind speed, and mean sea level information in the coastal regions surrounding Puerto Rico, as well as on the island itself. These variables have been correlated to predictable habitats for the mosquito vector carrying the dengue virus.

SMAP and 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. OLI, MODIS, AVHRR, and VIIRS will be utilized to derive a Vulnerability Index of dengue on the island using parameters related to sea surface temperature, sea level pressure, and mean sea level. AIRS will be utilized to derive this index using parameters related to air surface temperature and wind speed, which also affect the habitat suitability of the mosquito vector.

**Ancillary Datasets:**

- Dengue fever cases - 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 infections in Puerto Rico- Sentinel Enhanced Dengue Surveillance System (SEDESS)
- *In-situ* datasets provided by Dr. Pablo Mendez-Lazaro pertaining to rainfall, air surface temperature, sea surface temperature, sea level pressure, wind speed, mean sea level
- Projected temperature and precipitation- Coupled Model Intercomparison Project Phase 5 (CMIP 5)
- Elevation data – NOAA Puerto Rico, PR 1 arc-second MHW DEM

**Models:**

TerrSet - Habitat and Biodiversity Modeler (POC: James Toledano, Clark Labs/ Clark University and Andrew Nguyen, DEVELOP National Program)

Marine Geospatial Ecology Toolbox - Random Forests (POC: Andrew Nguyen, DEVELOP Center Lead, Ames Research Center)

## Decision Support Tools & Analyses:

| Proposed End Products | Decision Impacting | Current Partner Tool/Method |
|---|---|---|
| Vulnerability Index | Show where dengue is most likely prevalent in Puerto Rico for 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 |
| Early Warning System of Vector-borne diseases in Puerto Rico | Provide data to enable the early warning of possible outbreaks of dengue. This will help researchers, hospitals, and citizens of Puerto Rico understand the risk of dengue in their surrounding area, and enable decision-makers to localize their resources in the most heavily affected areas. | In-situ data |
| Time Series of Past Outbreaks | Show where dengue outbreaks 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 greatest concern. | N/A |
| Statistical Results from the Indices | Provide a better understanding of the amount each variable contributes to dengue. This will assist the Department of Health and CDC in prescribing preventative health measures to Puerto Ricans. | N/A |

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|---|---|---|
| Vulnerability Index Tool and Tutorial | Allows end users the ability to recreate results and provides a tool for future research opportunities. | N/A |

*Vulnerability Index* – This index will demonstrate which areas of Puerto Rico are most at risk of the dengue vector, which will provide early detection of this disease, as well as other vector-borne diseases on the island. It will incorporate rainfall, air surface temperature, sea surface temperature, sea level pressure, wind speed, and mean sea level data.

*Early Warning System of Vector-borne Diseases in Puerto Rico* – This risk map will enable the early warning of the general public on possible outbreaks of dengue and will be based on past and actual rainfall, temperature, and other physical variables that may affect the onset of the disease and proliferation of the vector. The database will be a set of GIS layers showcasing the results from the Vulnerability Index. It will also provide an idea to the general public of which parts of the island have a higher risk of increase in the dengue mosquito vector.

*Time Series of Past Outbreaks* – The time series allows a visualization of historical dengue outbreaks within Puerto Rico. This product will be useful for providing policy makers, and the public, with a better understanding regarding the severity of dengue.

*Statistical Results from the Index* – These results will ascertain the respective correlations to climatic variables of interest. We will use Principal Component Analysis, Pearson correlation coefficient, and either the Mann-Kendall trend test or a logistic regression. These analyses will determine possible relationships between the climatic variables of interest, analyze the correlation between dengue presence and the climatic variables of interest, and assess the significance of the time series trend that will be produced.

*Vulnerability Index Tool and Tutorial* – This tool and tutorial will be useful for end-users to apply the index for future use.

## Project Details:

**National Application Areas Addressed:** Health and Air Quality, Climate
**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.

**Study Location:** Puerto Rico
**Period being Studied:** 1994, 1998, 2007, 2010

**Advisor:** Dr. Juan Torres-Perez (Bay Area Environmental Research Institute)
**# of Participants Requested:** 4

**Project Timeline:** 2 Terms: 2015 Fall to 2016 Spring
**Multi-Term Objectives:**

- **Term 1** – The Fall of 2015 will focus on deriving a Vulnerability Index incorporating rainfall, air surface temperature, sea surface temperature, sea level pressure, wind speed, and mean sea level data. This term will also focus on creating a database of data related to vector-borne diseases on the island.
- **Term 2 (Proposed Term)** – The Spring of 2016 will be centered on future projections of dengue outbreaks within Puerto Rico. Team members will also develop an end-user tutorial for utilizing the Vulnerability Index.

**Previous Related DEVELOP Work:**
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

**Software & Scripting Requested:**

- ArcGIS - Raster Manipulation/Analysis, Image Enhancement & Map Creation of Landsat OLI, NPP VIIRS, Aqua/Terra MODIS
- TerrSet IDRISI- Ecological Modeling, Image Processing and Interpretation
- R- Statistical Analysis - Principal Component Analysis, Pearson Correlation Coefficient, Mann-Kendall Trend Test

**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., 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.