ACADEMIA | Letters

Advanced Early Dengue Prediction and Exploration Service (AEDES)

Dominic Vincent Ligot, University of Asia and the Pacific
Mark Toledo, CirroLytix Research Services

Abstract

This paper presents Project AEDES, a big data early warning, and surveillance system for dengue. The project utilizes Google Search Trends to detect public interest and panics related to dengue. Using Google Search Trends, precipitation, and temperature readings from climate data, the system nowcasts probable dengue cases and dengue-related deaths. The system utilizes FAPAR, NDVI, and NDWI readings from remote sensing to detect likely mosquito hotspots to prioritize interventions. We discuss the origin and development of the project and recent developments. We also discuss the current state of development and directions for further work.

Introduction

In 2019, the Philippines experienced its worst dengue epidemic in five years (Yee, 2019) with over 271,000 cases and more than 1,100 deaths as of August 2019 (DOH, 2019). Data on dengue takes time to be manually gathered which hampers the health sector's ability to deal with the threat. Dengue is spread between infected cases through the Aedes Aegypti mosquito (Chan & Johansson, 2012) and mosquitoes are known to breed in damp locations and stagnant water pools (Pinchoff, Silva, Spielman, & Hutchinson, 2021).

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.

Project AEDES was conceived as an entry in the annual NASA International Space Apps Challenge for a challenge called "Smash Your SDGs" – which called for creative solutions that utilize remote sensing Earth observations to address the United Nations' Sustainable Development Goals (SDGs) (The United Nations, 2021). The challenge involved combining satellite data and data obtained via crowd-sourcing and local data to address societal challenges across water, health, food security and/or land-use domains (NASA, Smash your SDGs!, 2019).

We proposed an automated information portal that correlates dengue cases and deaths with real-time data from climate, google searches, and satellite maps, giving an advance indicator of when dengue will emerge and potential dengue hotspot locations. This portal is accessible publicly but is targeted towards public health and local government agencies to give them advanced notice of dengue outbreaks and help prioritize resources.

a) First, precipitation and temperature climate create mosquito-breeding environments b) Mosquitoes spread and get infected by existing dengue cases, thereby spreading the disease c) New infections cause alarm which drives internet searches for dengue d) Dengue cases result in deaths e) Cases and deaths are reported to public health officials

Therefore, by detecting *a* and *c* early, we hopefully disrupt the disease cycle before an epidemic spreads.

Related Work

Researchers have already successfully predicted dengue cases (R 0.8) in the Visayas region of the Philippines using an Artificial Neural Network (ANN) which used climate data such as temperature and rainfall and a lagged number of previous dengue cases (Datoc, Caparas, & Caro, 2016). Internet searches for 'dengue' and related keywords have also been used to successfully predict dengue cases in Mexico, Brazil, Thailand, Singapore, and Taiwan (Yang, et al., 2017).

For hotspot detection, researchers have proposed a process involving vegetation (FAPAR, NDVI) and moisture readings from remote sensing to detect stagnant water pools (Chua, 2019). Vegetation indices and biophysical variables (NDWI, NDVI, FAPAR) have been used for water footprint assessment (Stancalie, Nertan, Toulios, & Spiliotopoulos, 2014).

Incubation periods for dengue can vary by temperature, between 5 and 33 days at 25C and 2 and 15 days at 30C, with means of 15 and 6.5 days respectively, suggesting that climate can be used as a driver for observing the development of the disease (Chan & Johansson, 2012).

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. `https://doi.org/10.20935/AL2956`.

Methods

The proposed service relies on remote sensing readings for NDVI (NASA, Normalized Difference Vegetation Index (NDVI), 2021), FAPAR (Weiss & Baret, 2011), and NDWI (EOS, 2021) from Sentinel-2 Copernicus (ESA, 2021) and Landsat 8 (USGS, 2017). The local temperature and rainfall readings were obtained from the local weather bureau. Google searches for 'dengue', 'dengue symptoms', 'dengue fever', and 'dengue medicine' were downloaded from Google Search Trends (Google, 2021). Dengue cases were obtained from the local Department of Health's statistics page (DOH, 2019).

Using QGIS (QGIS, 2021), the following remote sensing bands from the Sentinel 2 and Landsat 8 were extracted:

- Sentinel - Green
- Sentinel - Red
- Sentinel - Near-Infrared (NIR)
- Landsat 8 - Green
- Landsat 8 - Red
- Landsat 8 - Near-Infrared (NIR)

The indices were calculated as follows:

- NDVI, FAPAR = (NIR - Red) / (NIR + Red)
- NDWI = (Green - NIR) / (Green + NIR)

Once calculated the readings were extracted as long-lat coordinates via QGIS.

Using the google search trends from 2017 – 2019, we noted that dengue searches spiked at almost regular intervals every July-August and December-January however the locations varied every year. For the prototype, we decided to focus National Capital Region (Quezon City), Eastern Visayas (Tacloban City), Western Visayas (Iloilo City), and the BARMM region (Cotabato City) due to the availability of local weather station data in these areas and these areas experienced the highest spikes in searches at the time of our extraction (July 2019).

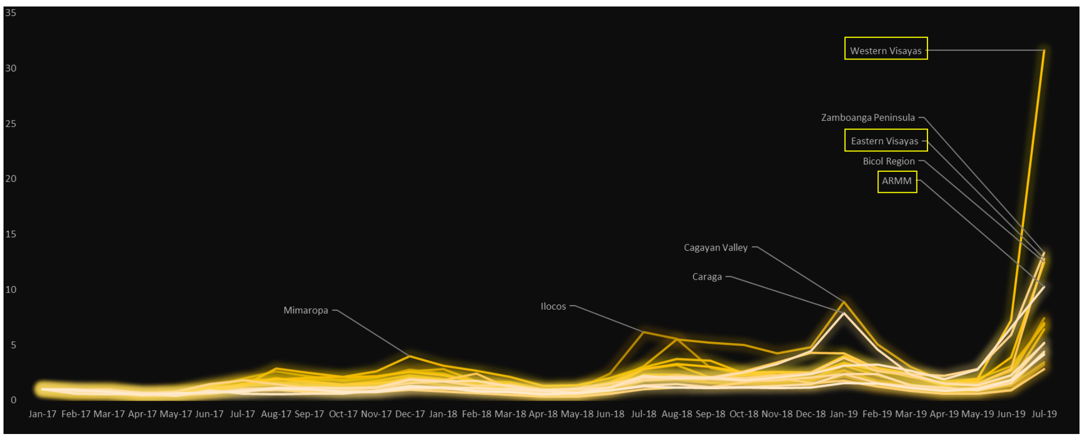
For nowcasting, we performed multivariate linear regression using temperature, rainfall, and google search indices to fit against the dengue cases. We performed a step-wise procedure

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.

to optimize and test various combinations of independent variables, then selected the top 3 fitting models for each location.

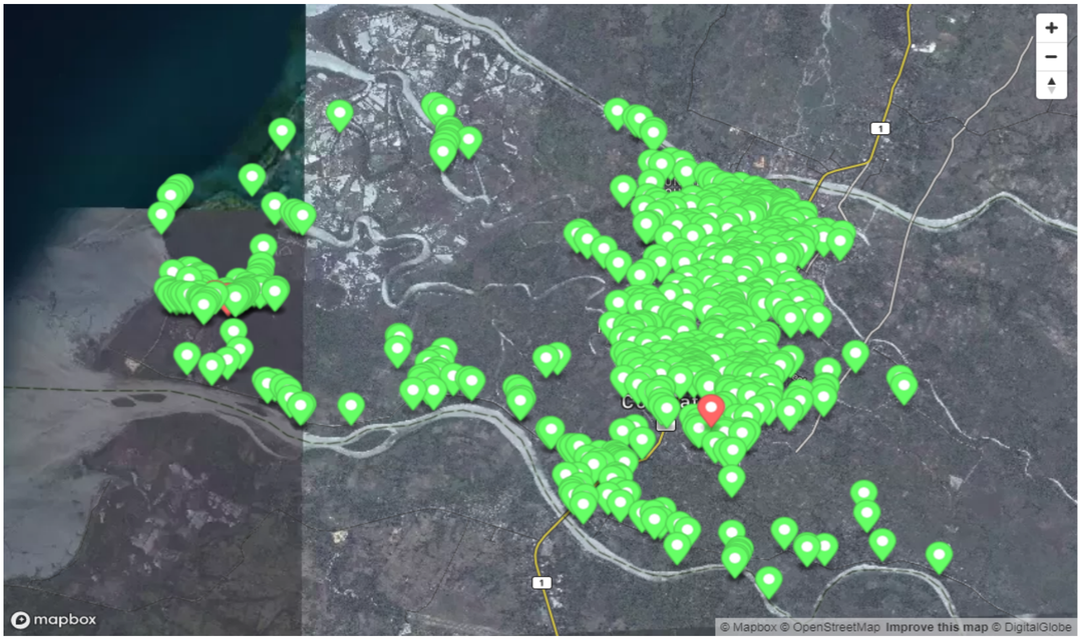
For the web application, a vanilla web stack (HTML, CSS, Javascript, PHP). Charts were prepared using Chart.js (Timberg, Kurkela, McCann, & Linsley, 2021). Mapping applications used ping OpenStreetMap (OSM, 2021) on Mapbox API (Mapbox, 2021) (free-tier). Statistical modeling was performed using Python on Jupyter notebooks with SciKit-Learn (du Boisberranger, Van den Bossche, Estève, & Fan, 2021) and StatsModels (Taylor, 2021) libraries.

Results

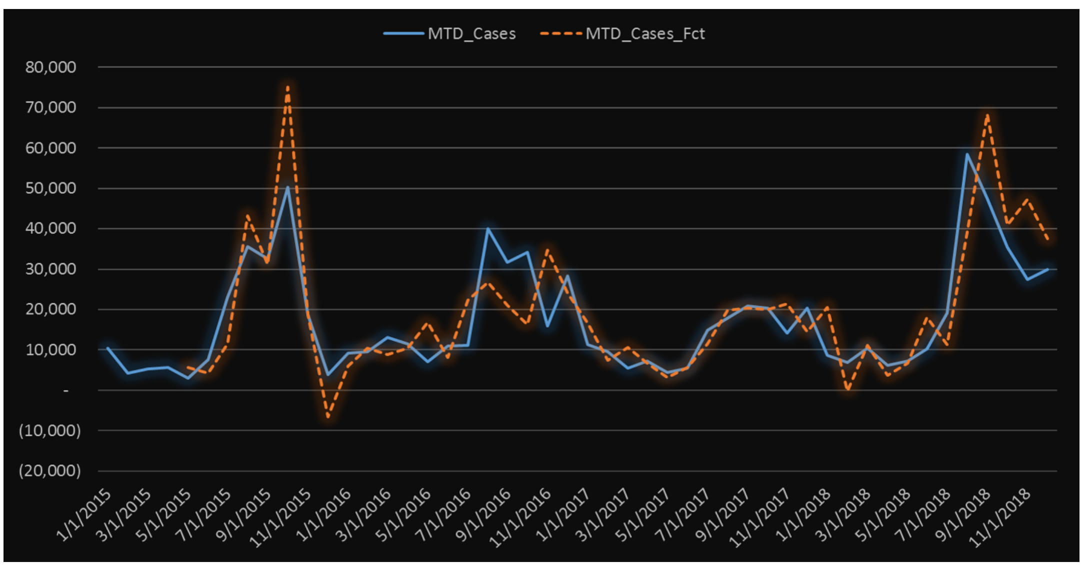


We visualized the google search trends for dengue panics in Figure 1.

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.



We also visualized maps of detected hotspots as in Figure 2.



We visualized the fit of one of the nowcasting models in Figure 3.

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. `https://doi.org/10.20935/AL2956`.

The modeling fitting results were as follows:

- Philippines total (see Figure X)
  - Model 1 (R 0.75, R2 0.56)
  - Model 2 (R 0.73, R2 0.53)
  - Model 3 (R 0.75. R2 0.57)
- NCR – Quezon City
  - Model 1 (R 0.84, R2 0.7)
  - Model 2 (R 0.84, R2 0.71)
  - Model 3 (R 0.83, R2 0.69)
- Eastern Visayas – Tacloban City
  - Model 1 (R 0.75, R2 0.57)
  - Model 2 (R 0.76, R2 0.58)
  - Model 3 (R 0.73, R2 0.53)
- Western Visayas – Iloilo City
  - Model 1 (R 0.9, R2 0.81)
  - Model 2 (R 0.89, R2 0.79)
  - Model 3 (R 0.9, R2 0.81)
- ARMM – Cotabato City
  - Model 1 (R 0.87, R2 0.76)
  - Model 2 (R 0.86, R2 0.74)
  - Model 3 (R 0.81, R2 0.66)

Discussion

Through this solution we are addressing 2 key challenges for public health and local government officials: a) Get ahead of the lagged delay of dengue reporting by using real-time information (e.g. climate, searches) to infer if dengue cases and deaths are about to spike; b)

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.

precisely anticipate areas that may be affected by dengue to prioritize health aid, supplies, and proactive fumigation to prevent the outbreaks.

Based on August 2019 figures, dengue deaths are averaging 138 lives a month with 34,000 new cases emerging every month. This translates to 5 lives and more than 1,100 cases saved every day we cut the response time.

Current developments

The entry was awarded the Global Best Use of Data in the 2019 challenge among 2,067 projects (NASA, Awards & Recognition, 2019). Development continued during the onset of the COVID-19 pandemic and lockdowns, and the portal is currently on its 4th iteration. In November 2020, the Group on Earth Observations (GEO) awarded the Earth Observations for SDG award (EO4SDG) for using remote sensing to help solve SDG 3 (GEO, 2020). UNICEF and the Digital Public Goods Alliance vetted the solution shortly after and in May 2021, it has been recognized as a digital public good (Digital Public Goods Alliance, 2021).

Development on the solution continues and expected changes include the implementation of a risk management framework inspired by the EU JRC INFORM (Poljanšek, Marin-Ferrer, Vernaccini, & Messina, 2018) to flesh out insights on societal and environmental vectors for dengue.

We hope to get the solution funded for a comprehensive national public health campaign to educate local government and health sector offices on the use of data to prevent dengue. Beyond the Philippines, the application is also relevant to other countries that are suffering from dengue as well as other mosquito-borne diseases such as Zika and Chikungunya (same mosquito as dengue: Aedes Aegypti) (CDC, Transmission Through Mosquito Bites, 2021) and Malaria (Anopheles Mosquito) (CDC, Malaria Biology, 2021).

Acknowledgements

The authors thank members of the original AEDES team: Claire, Jansen, scholars from FTW Foundation who enhanced the solution: Mok, Janine, and Rache, and collaborators: Cricket, Mike P., Wilson, Thaddeus, Mike D., Mark, Emily, Sam, and Jhen.

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.

References

CDC. (2021). *Malaria Biology*. Retrieved from cdc.gov: https://www.cdc.gov/malaria/about/biology/index.html

CDC. (2021). *Transmission Through Mosquito Bites*. Retrieved from cdc.gov: https://www.cdc.gov/dengue/transmission/index.html

Chan, M., & Johansson, M. (2012). The Incubation Periods of Dengue Viruses. *PLoS ONE*. doi:https://doi.org/10.1371/journal.pone.0050972

Chua, W. (2019). *Project Still Water*. Retrieved from github.com.

Datoc, H., Caparas, R., & Caro, J. (2016). Forecasting and data visualization of dengue spread in the Philippine Visayas island group. *2016 7th International Conference on Information, Intelligence, Systems & Applications (IISA)*. doi:https://doi.org/10.1109/IISA.2016.7785420

Digital Public Goods Alliance. (2021). *UNICEF Philippines announces its first Digital Public Good Pathfinding Pilot*. Retrieved from digitalpublicgoods.net/: https://digitalpublicgoods.net/blog/unicef-philippines-announces-its-first-digital-public-good-pathfinding-pilot/

DOH. (2019). *Monthly Dengue Report No. 8*. Retrieved from doh.gov.ph: https://doh.gov.ph/sites/default/files/statistics/2019%20Dengue%20Monthly%20Report%20No.%208.pdf

du Boisberranger, J., Van den Bossche, J., Estève, L., & Fan, T. (2021). *scikit-learn*. Retrieved from scikit-learn.org: https://scikit-learn.org/stable/index.html

EOS. (2021). *NDWI*. Retrieved from eos.com: https://eos.com/make-an-analysis/ndwi/

ESA. (2021). *Access to Sentinel data via download*. Retrieved from esa.int: https://sentinel.esa.int/web/sentinel/sentinel-data-access

GEO. (2020). *Announcing the winners of the 2020 Earth Observation for the Sustainable Development Goals Awards*. Retrieved from www.earthobservations.org/: https://www.earthobservations.org/geo_blog_obs.php?id=472

Google. (2021). *Google Trends*. Retrieved from google.com: https://trends.google.com/trends/?geo=PH

Mapbox. (2021). *Mapbox*. Retrieved from mapbox.com: https://www.mapbox.com/

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. `https://doi.org/10.20935/AL2956`.

NASA. (2019). *Awards & Recognition*. Retrieved from 2019.spaceappschallenge.org: https://2019.spaceappschallenge.org/awards

NASA. (2019). *Smash your SDGs!* Retrieved from 2019.spaceappschallenge.org: https://2019.spaceappschallenge.org/challenges/living-our-world/smash-your-sdgs/details

NASA. (2021). *Normalized Difference Vegetation Index (NDVI)*. Retrieved from nasa.gov: https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php

OSM. (2021). *OpenStreetMap*. Retrieved from openstreetmap.org: https://www.openstreetmap.org

Pinchoff, J., Silva, M., Spielman, K., & Hutchinson, P. (2021). Use of effective lids reduces presence of mosquito larvae in household water storage containers in urban and peri-urban Zika risk areas of Guatemala, Honduras, and El Salvador. *Parasites Vectors*. doi:https://doi.org/10.1186/s13071-021-04668-8

Poljanšek, K., Marin-Ferrer, M., Vernaccini, L., & Messina, L. (2018). *INFORM Epidemic Risk Index*. Retrieved from drmkc.jrc.ec.europa.eu/: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/INFORM-Epidemic-Risk-Index

QGIS. (2021). *QGIS A Free and Open Source Geographic Information System*. Retrieved from qgis.org: https://www.qgis.org/en/site/

Stancalie, G., Nertan, A., Toulios, L., & Spiliotopoulos, M. (2014). Potential of using satellite based vegetation indices and biophysical variables for the assessment of the water footprint of crops. *SPIE 9229, Second International Conference on Remote Sensing and Geoinformation of the Environment*. doi:https://doi.org/10.1117/12.2066392

Taylor, J. (2021). *Statsmodels*. Retrieved from statsmodels.org: https://www.statsmodels.org/stable/index.html

The United Nations. (2021). *The 17 Goals*. Retrieved from un.org: https://sdgs.un.org/goals

Timberg, E., Kurkela, J., McCann, B., & Linsley, T. (2021). *Chart.js*. Retrieved from chartjs.org: https://www.chartjs.org/

USGS. (2017). *Landsat 8.* Retrieved from usgs.gov.

Weiss, M., & Baret, F. (2011). *fAPAR (fraction of Absorbed Photosynthetically Active Radia-*

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. `https://doi.org/10.20935/AL2956`.

tion) estimates at various scale. Retrieved from www.semanticscholar.org/: https://www.semanticscholar.org/paper/fAPAR-%28-fraction-of-Absorbed-Photosynthetically-%29-Weiss-Baret/d178bd58b51fd18c2b97b07aa5c6154d49562a87?p2df

Yang, S., Kou, S., Lu, F., Brownstein, J., Brooke, N., & Santillana, M. (2017). Advances in using Internet searches to track dengue. *PLoS Computational Biology*. doi:https://doi.org/10.1371/journal.pcbi.1005607

Yee, J. (2019). *DOH: Dengue cases highest in five years*. Retrieved from inquirer.net: https://newsinfo.inquirer.net/1152330/doh-dengue-cases-highest-in-five-years

Corresponding Author: Dominic Vincent Ligot, dominic.ligot@cirrolytix.com
Citation: Ligot, D.V., Toledo, M. (2021). Advanced Early Dengue Prediction and Exploration Service (AEDES). *Academia Letters*, Article 2956. https://doi.org/10.20935/AL2956.