**Ellicott City Disasters III**

*Building a Real-Time Predictive Flood Model for Improving Early Warning Systems in Ellicott City, Maryland*

**Project Team**

***Project Team:***

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***Partner POC:*** Brian Cleary, bcleary@howardcountymd.gov

**Project Overview**

***Project Synopsis:***

This project incorporated NASA Earth observations and other publicly available resources to create a real-time flood prediction tool for Ellicott City, Maryland. The tool, titled Sequentially Trained Real-time EstimAted Model (STREAM), incorporated NASA Earth observations, National Weather Service modeled weather products, and stream gauges from the Howard County Office of Emergency Management (OEM). The team also integrated the real-time model output into the OEM’s online data portal, OneRain. With these end products, Howard County OEM will be better equipped to make decisions to mitigate flood risks in Ellicott City.

***Abstract:***

As flood events in the United States grow in frequency and intensity, the uses of applied remote sensing analyses are increasingly necessary for effective flood monitoring and warning systems. The NASA DEVELOP Ellicott City Disasters III project investigated the use of machine learning for applications in flood risk detection to support the improvement of early warning systems in Ellicott City, Maryland. To strengthen the efforts of the Howard County Office of Emergency Management (OEM) in building a more robust flood monitoring system, this term built on the predictive capability of the long-short term memory (LSTM) model created by the second term of this DEVELOP project to create a Sequentially Trained Real-time EstimAted Model (STREAM). Enhancements to the model included the integration of both real-time and predicted weather products from the National Weather Service to increase predictive capacity. These weather products were supplemented by stream gauge data from the OEM as well as real-time radar products. The resultant flood risk model was trained to evaluate input variables and predict stage height in Ellicott City in real time. The model, upgraded to predict stage height up to 8 hours in advance, was incorporated into an online dashboard in a user-friendly interface. The project demonstrated the potential for integration of open data and NASA Earth observations into a flood risk forecasting tool capable of informing real-time decision-making.

***Key Terms:***

flooding, extreme events, deep learning, machine learning, runoff

***National Application Areas Addressed:*** Disasters, Urban Development, Transportation & Infrastructure

***Study Location:*** Howard County, MD

***Study Period:*** January 2011 to December 2019

***Community Concerns:***

* Ellicott City, MD has suffered from increasingly frequent and severe flood events in the past decade, experiencing two 1000-year flood events over the course of three years.
* Current emergency management protocols hold the potential to integrate additional data and technology to respond to rapidly forming threats.
* Preemptive action could save lives and millions of dollars in property damage.

***Project Objectives:***

* Enhance Howard County’s early warning system by developing a real-time flood prediction model to forecast stage height up to 8 hours in advance
* Integrate STREAM model outputs into a user-friendly interface that functions as a real-time decision support tool

***Previous Terms:***

2020 Spring (GSFC) – Ellicott City Disasters II

2019 Summer (GSFC) – Ellicott City Disasters

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Howard County Government, Office of Emergency Management** |

|  |
| --- |
| Mike Hinson, Acting Emergency Management Director |

 | End User | No |
| **Howard County Government, Storm Water Management Division** | Brian Cleary, Project Manager | Collaborator | No |
| **NOAA, National Weather Service, Baltimore-Washington Weather Forecast Office** | Christopher Strong, Warning Coordination Meteorologist | Collaborator | No |

***Decision-Making Practices & Policies:***

The Howard County OEM develops and maintains emergency management plans that encompass emergency response as well as disaster recovery, mitigation, and protection. The OEM also provides guidance to governmental and emergency response agencies on the development of disaster management plans. To support these endeavors, the OEM staff conduct countywide planning, training, and exercise programs to help the county prepare for emergencies. In addition, the OEM staff manage and coordinate Howard County’s Emergency Operations Center (EOC) during times of emergency management activation. Currently, Howard County’s OEM makes decisions using WebEOC emergency management technologies, such as cameras and live updates from the National Weather Service and Maryland Department of Transportation. To create a more robust flood preparedness strategy, the OEM is interested in integrating NASA Earth observations into the existing emergency response framework. More specifically, Ellicott City’s “Safe and Sound” plan features the development of a threat matrix that stands to benefit from the use of near real-time data integration into flood severity predictions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **GOES-16 ABI** | Rainfall Rate, Forecasted Precipitation Estimation, Radiances, Motion Vectors | Used in modeled weather products (High-Resolution Rapid Refresh (HRRR) atmospheric model) |

***Ancillary Datasets:***

* High Resolution Rapid Refresh (HRRR) – Real-time precipitation forecasts to inform the model and bolster its predictive capacity.
* Howard County stream gauge current and past measurements (Hudson Branch) – *In situ* measurements for model validation and inputs for prediction of stage height.

***Software & Scripting:***

* Python 3.7 – Numpy, Keras, Tensorflow, Scikit-learn (primary libraries) for model development
* Google Colaboratory – Scripting environment for model development

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Sequentially Trained Real-time EstimAted Model – Ellicott City Flood Risk Model** | GOES-16 ABI | A real-time flood risk model that includes inputs such as *in situ* stream gauge measurements, real-time precipitation data, modeled weather products, and real-time radar. Partners can view iterative model outputs on an interactive platform called OneRain.  | IV |
| **Esri StoryMap** | GOES-16 ABI | A creative and visual deliverable that demonstrates the severity of flood issues while highlighting the utility of the STREAM product. Partners can use the StoryMap as a communication tool to inform the public about how the model works.  | N/A |

***Product Benefit to End User:***

STREAM will support the emergency management actions of the Howard County OEM by providing continuous flood risk forecasting through an interactive online platform. The online application can support proactive, real-time, decision-making during potential flooding events, allowing the OEM to better direct resources where necessary and inform citizens of potential risk.

**References**

Kratzert, F., Klotz, D., Brenner, C., Schulz, K., & Herrnegger, M. (2018). Rainfall--runoff modelling using Long Short-Term Memory (LSTM) networks. *Hydrology and Earth System Sciences, 22,* 6005-6022. <https://doi.org/10.5194/hess-22-6005-2018>

Schulz, A., Cunningham, S., Donesky, J., Pruett, M. (2020). Ellicott City Disasters II: Enhancing a statistical flood risk model to continue improving early warning systems and public safety in Ellicott City, Maryland. NASA Goddard Space Flight Center.

Xiang, Z., Yan, J., Demir, I. (2020). A rainfall-runoff model with LSTM-based sequence-to-sequence learning. *Water Research Research, 56*(1),910-922*.* <https://doi.org/10.1029/2019WR025326>