**Ellicott City Disasters**

*Applying NASA Resources to a Statistical Flood Risk Model to Improve Early Warning Systems and Public Safety*

**Project Team**

***Project Team:***

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***Advisors & Mentors:***

Dr. John Bolten (NASA Goddard Space Flight Center)

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Dr. Sujay Kumar (NASA Goddard Space Flight Center)

**Project Overview**

***Project Synopsis:*** In 2016 and 2018, Ellicott City, Maryland was the victim of two severe flood events that destroyed lives and property. This project sought to support the efforts of the Howard County Office of Emergency Management (OEM) through the development of a flood severity model, which represents a step in improving early warning systems and risk modeling capabilities using NASA Earth observations and open data sources.

***Abstract:***

As flooding events in the United States grow in frequency and intensity, the use of technological advancements and applied science is increasingly necessary for effective flood monitoring and warning systems. Governments are exploring new ways of using science and technology to solve public safety and environmental problems. The NASA DEVELOP Ellicott City Disasters project investigated two extreme flood events in 2016 and 2018 within Ellicott City, Maryland. The project supported the efforts of the Howard County Office of Emergency Management (OEM) and represents the first step in improving early warning system capabilities using open data and NASA Earth observations. The resultant flood model (“Flood Learning Model Environment” or FLuME) evaluated the statistical significance of features engineered from NASA resources such as North American Land Data Assimilation System (NLDAS) and Soil Moisture Active Passive (SMAP), and utilized stream gauge data from the Department of Homeland Security, OEM, and the United States Geological Survey. The project products included data visualizations and a model framework for exploring factors influencing flood severity. The model was trained on two years of discharge data and was subsequently used to hindcast the May 2018 flood of Ellicott City. This exploratory analysis informs OEM decision-making processes and will help the county effectively allocate monitoring technology within the Patapsco watershed, thereby increasing public safety and reducing risk.

***Keywords:***

flood risk, statistical modeling, SMAP, NLDAS, machine learning, emergency management, remote sensing

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

***Study Location:*** Ellicott City, MD

***Study Period:* *Study Period:*** January 2016 to May 2019

***Community Concerns:***

* Ellicott City, Maryland has suffered from increasingly frequent and damaging floods in the past decade.
* Effective use of data and technology can improve emergency management protocols.
* Preemptive action could save human lives and millions of dollars in property damage.

***Project Objectives:***

* Use NASA Earth observations to examine flood events in Ellicott City
* Model factors that contribute to flood events
* Give feedback to inform monitoring technology and resource allocation across space, with a focus on ground-level data collection
* Identify other datasets necessary for accurate flood modeling at a scale useful for decision-making

**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, Stormwater 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 Office of Emergency Management (OEM) oversees emergency response throughout Howard County. It is responsible for ensuring that local emergency response agencies are knowledgeable and prepared to manage disaster events and recovery efforts. OEM staff provides training to these agencies to ensure preparedness for natural, technological, and man-made emergencies. They also staff the Emergency Operations Center (EOC) during emergencies. Current OEM decision-making tools include WebEOC emergency management technology, cameras, and connections to the National Weather Service and the Maryland Department of Transportation. The current system does not incorporate remote sensing datasets or predict floods beyond a 30-minute window.

***Project Benefit to End User:***

The statistical flood model and data visualizations will supplement the efforts of OEM by clarifying the correlation between various parameters and historical flooding in Ellicott City. The model output can be integrated into existing OEM tools, such as a threat matrix and WebEOC dashboards, thereby incorporating predictive capabilities into these tools. This enhancement will allow decision-makers to recognize the conditions characteristic of a flood event prior to occurrence.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **SMAP L-band Radiometer** | Soil moisture | Soil moisture data were used to supplement flood model analyses. |
| **Aqua AMSR-E** | Precipitation | Total hourly precipitation (dis-aggregated from daily gauge data using Aqua and TRMM) was used as an input variable for the machine learning model. |
| **TRMM TMI** | Precipitation | Total hourly precipitation (dis-aggregated from daily gauge data using Aqua and TRMM) was used as an input variable for the machine learning model. |

***Ancillary Datasets:***

* NASA North American Land Data Assimilation System (NLDAS-2) – Near real-time precipitation model comparisons bolstered modeling capabilities
* NOAA National Weather Service Radar Data Related to the Floods of 2016 and 2018 in Ellicott City – These data were used to reconstruct the previous two major floods to show users how the system is anticipated to work
* NOAA National Weather Service Stream Gauge Data Related to the Floods of 2016 and 2018 in Ellicott City – These data were used to reconstruct the previous two major floods to show users how the system is anticipated to work
* Department of Homeland Security Preinstalled Stream Gauge Monitor Data – *In situ* measurements were used for validation and flood model inputs
* US Census Bureau TIGER dataset – Primary and secondary roads were identified and incorporated into visualizations
* USGS 3D Elevation Program (3DEP) – 3.4 m resolution elevation data were used to derive aspect and slope for visualizations
* USGS Daily Streamflow Conditions Data – *In situ* measurements were used for validation and flood model inputs

***Software & Scripting:***

* Python 3.7 – Statistical flood modeling
* PyTorch 1.1 – Machine learning package
* Esri ArcGIS Pro 2.3 – Raster manipulation and analysis, imagery processing, and map production

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Flood Learning Model Environment (FLuME)**  | SMAP L-band RadiometerAqua AMSR-ETRMM TMI | The flood model will be used by the Howard County Office of Emergency Management to improve its early emergency warning system capabilities and enhance its decision-making processes. | IV |
| **Ellicott City Information Maps** | SMAP L-band RadiometerAqua AMSR-ETRMM TMI | Ellicott City information maps derived from NASA data will inform interpretation of model outputs. | N/A |
| **FLuME Tutorial** | N/A | The flood risk model tutorial will graphically demonstrate how to apply and analyze the flood risk model. | N/A |

**Project Handoff Package**

***Transition Plan:*** Digital visualization end products were provided during an in-person and virtual handoff in Week 9 during which the team discussed results and answered any questions regarding the products. The Software Release Process was required for FLuME; partners will receive it when the process is complete.

***Software Release Plan:*** FLuME will undergo the NASA Software Release Process that extends past the end of the term. Both the team POC and software release POC will communicate with the partners throughout this process, ensuring that their questions and needs are addressed.

***Team POC:*** Terra Edenhart-Pepe, terra.edenhart@gmail.com

***Software Release POC:*** Callum Wayman, callum.wayman@gmail.com

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

***Handoff Package:***

* Ellicott City Information Maps and Graphics
* FLuME Tutorial
* Technical Paper
* Poster
* Presentation

**References**

Thakali, R., Bhandari, R., Kandissounon, G. A., Kalra, A., & Ahmad, S. (2017). Flood risk assessment using the updated FEMA floodplain standard in the Ellicott City, Maryland, United States. *Proceedings of the World Environmental and Water Resources Congress 2017* (pp. 280-291). Sacramento, California: American Society of Civil Engineers. Retrieved from https://digitalscholarship.unlv.edu/fac\_articles/449