**NASA DEVELOP National Program**

**2020 Summer Project Proposal**

**Maryland – Goddard**

**Ellicott City Disasters III**

*Building an Operational Threat Matrix based on Statistical Flood Modelling for Improving Early Warning Systems in Ellicott City, Maryland*

**Project Overview**

***Project Synopsis*:** This project will incorporate NASA Earth observations and other publicly available resources to connect the flood risk model previously designed for Ellicott City, MD with an operational hazard matrix to inform risk response. The Long Short Term Memory (LSTM) flood risk model, developed and enhanced by previous project terms, is based on NASA Earth observations and stream gauges from the Department of Homeland Security (DHS) and Howard County Office of Emergency Management (OEM). This term will further enhance the flood risk model to employ spatially-distributed information, taking advantage of techniques such as convolutional neural networks (CNNs). In addition, the project will build a tool for the OEM’s operational hazard matrix, which will integrate the LSTM model outputs and will enable partners to examine and visualize real-time flood risk. With these end products, Howard County OEM will be better equipped to make decisions to mitigate flood risks in Ellicott City.

***Community Concern:*** Over the past ten years, Ellicott City, MD has been the victim of multiple detrimental flooding events, which have claimed human lives and caused over 10 million dollars in infrastructural and property damage. While the town has grappled with these flooding issues for over 100 years, the local flooding dynamics are changing in both frequency and intensity. Flooding events are projected to worsen with changing environmental conditions and increased urban development, thus escalating the need for better flood monitoring and prediction. Accurate, timely, and detailed data reports are necessary to mitigate the effects of severe flooding in the region. Additionally, these flooding events have socioeconomic consequences that are not fully understood.

***Source of Project Idea:*** Maryland – Goddard’s Lead Science Advisor, Dr. John Bolten, approached relevant partners with the idea to improve flood monitoring in Ellicott City after the community was devastated by flooding events in 2018. Following the second project term, the Howard County OEM expressed interest in an additional term, which would serve to integrate the previous terms’ model with the County’s existing framework for a hazard matrix system. The team will design a cumulative hazard matrix.

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

Infrastructure, Water Resources

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

***Study Period:*** January 2011 – January 2020

***Advisors:*** Dr. John Bolten (NASA Goddard Space Flight Center), Brian Cleary (Howard County Storm Water Management Division), Dr. Sujay Kumar (NASA Goddard Space Flight Center)

**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 |

***End User Overview***

***End User’s Current Decision-Making Process:***The Howard County OEM develops and maintains emergency management plans that encompass emergency response as well as disaster recovery, mitigation, and protection. OEM also provides guidance to governmental and emergency response agencies on the development of disaster management plans. OEM staff conduct countywide planning, training, and exercise programs to help the County prepare for natural, technological, and man-made emergencies. In addition, OEM staff manage and coordinate the County's Emergency Operations Center (EOC) during times of emergency management activation. Currently, OEM makes decisions using WebEOC emergency management technologies like cameras and live updates from the National Weather Service and Maryland Department of Transportation. Additionally, OEM has developed the framework for a threat matrix that can help prioritize decisions based on an early warning system.

***End User’s Capacity to Use NASA Earth Observations:***

*Howard County Government, Office of Emergency Management* – Howard County OEM currently does not use NASA Earth observation data in its operations. OEM leadership has expressed interest in learning more about what other data sources exist and how they can use them to improve their situational awareness and decision making.

***Collaborator Overview***

***Collaborator Support:***

*Howard County Government, Stormwater Management Division* – The Stormwater Management Division will provide ancillary flood risk model inputs, project advising, and feedback on flood risk model design. This office is responsible for managing the quality and quantity of stormwater that originates in, falls onto, or passes through Howard County.

*NOAA, National Weather Service, Baltimore-Washington Weather Forecast Office* – NOAA NWS will provide ancillary flood risk model inputs and feedback on flood risk model design. This office is responsible for issuing warnings for Ellicott City, MD and can provide additional model input data as necessary.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The Project Lead will serve as the primary point of contact for communication with the project partners and advisors. The team will communicate with project partners through biweekly teleconferences and weekly email updates.

***Transition Plan*:** Digital visualization end products will be provided during a virtual handoff in Week 9, where the team will discuss results and answer any questions regarding the products. This will include a half-day virtual workshop with the primary end users, where the partners will be guided through how to use the model’s outputs in combination with the hazard matrix. Software release will likely be required for the interactive tool, delaying partner application of the tool until software release is complete. However, software release of the FLASH model (Flood Learning Environment and Severity Assessment Hub) is currently underway, and if completed by this time, the team can share this code with the partners as well. For use of the tool, a more detailed tutorial will be constructed and given to the partners at the time of software release.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua AMSR-E** | Precipitation, surface wetness, soil moisture | Precipitation, surface wetness, and soil moisture data will be used to supplement flood risk analyses and add additional parameters to the flood risk model. |
| **TRMM TMI** | Precipitation | Precipitation data will be used to supplement flood risk analyses. |
| **SMAP L-band Radiometer** | Soil moisture | Soil moisture data will be used to supplement flood risk analyses. |

***Ancillary Datasets:***

* NOAA NWS Radar Data Related to the Floods of 2011, 2016 and 2018 in Ellicott City – Reconstruct the previous three major floods to show users how the system is anticipated to work
* NOAA NWS Stream Gauge Data Related to the Floods of 2011, 2016 and 2018 in Ellicott City – Reconstruct the previous three major floods to show users how the system is anticipated to work
* NOAA NWS Hydrologic Modeling Data Related to the Floods of 2011, 2016 and 2018 in Ellicott City –Reconstruct the previous three major floods to show users how the system is anticipated to work
* Department of Homeland Security Preinstalled Stream Gauge Monitor Data – Validation and flood model inputs
* US Census Bureau TIGER dataset – Spatially referenced socioeconomic data including age, population density, and percent below the poverty line will inform the hazard risk matrix, primary and secondary roads will be identified and incorporated into flood risk analysis
* Homeland Infrastructure Foundation-Level Data (HIFLD) – Infrastructure data for flood impact analysis
* NASA SPoRT Land Information System (LIS) – Flood model inputs will bolster modeling capabilities
* NASA North American Land Data Assimilation System (NLDAS-2) – Near real-time precipitation model comparisons will bolster modeling capabilities
* NASA SPoRT Multi-Radar Multi-Sensor (MRMS) – Flood model inputs will bolster modeling capabilities
* USGS 3D Elevation Program (3DEP) – 3.4 m resolution elevation data to derive aspect and slope for analysis
* USGS Daily Streamflow Conditions Data – *In situ* measurements for validation and flood model inputs
* Howard County Socioeconomic Data – Understand how flood risk relates to different demographics found in Howard County
* NASA Gridded Population of the World (GPW) – Estimates of population density in and around the watershed to understand risk

***Modeling:***

* Machine learning Environment for NASA Scientific data Applications (MENSA) (POC: Sujay Kumar, NASA Goddard Space Flight Center)
* Flood Learning Environment and Severity Hub (FLASH) (POC: Alina Schulz, Matthew Pruett, Jonathan Donesky & Scott Cunningham, DEVELOP at NASA Goddard Space Flight Center)

***Software & Scripting:***

* Python 3.7 – Statistical flood risk modeling
* R 3.6 – Data cleaning and processing
* Esri ArcGIS Pro 2.3 – Raster manipulation and analysis, imagery processing, and map production
* Google Earth Engine API – Data acquisition and image processing

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Operational Hazard Matrix Tool** | Partners will be able to use the tool to explore flood risk in real-time, statistically, and spatially, using this tool based on the model outputs and ancillary datasets which will help quantify risk.  | FLASH Model outputs, socioeconomic data from Howard County Department of Zoning and Planning, and TIGER Census data about infrastructure and population will all be used to assess the severity and potential impact of flooding. | IV |
| **Spatially Enhanced Flood Learning Environment and Severity Hub** (**FLASH) Model** | An improved flood risk model that incorporates spatially-distributed flood driver data will enable the partners to make decisions about mitigation strategies. | Stream gauge data, Aqua AMSR-E and TRMM TMI precipitation data, radar reflectivity, SMAP L-band soil moisture data, and existing precipitation and climate models from NASA SPoRT LIS will improve the existing model framework. | IV |

***End User Benefit*:** The operational hazard matrix tool and spatially enhanced FLASH model will supplement the emergency management actions of the Howard County OEM by improving the warning time of potential flood hazards, quantifying flood risk in real-time, and estimating its spatial extent. These outputs can help inform decision making when potential flooding conditions are either present or predicted, allowing the OEM to better direct its resources where necessary. Incorporating socioeconomic variables into the tool will also allow OEM to target resources where populations would benefit most.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 3 Terms: 2019 Summer, 2020 Spring, and 2020 Summer

***Multi-Term Objectives:***

* **Term 1:** 2019 Summer (GSFC) – Ellicott City Disasters
	+ The first term created and tested a flood risk model using NASA Earth observations and *in situ* data from stream gauge monitors installed by the Howard County OEM. The model, Flood Learning Model Environment (FLuME) predicted flood risk and evaluated the statistical significance of precipitation data from NASA’s North American Land Data Assimilation System (NLDAS) and soil moisture data from Soil Moisture Active Passive (SMAP). This model provided the foundation for an improved flood risk model and led to a better understanding of the ideal placements of stream gauges for future data collection.
* **Term 2:** 2020 Spring (GSFC) – Ellicott City Disasters II
	+ This project built upon the FLuME model created by the previous team and enhanced it to make it more detailed and accurate. The improved flood risk model, the Flood Learning Environment and Severity Hub (FLASH) added a dimension to the previous term’s model and generated a Long Short-term Memory model (LSTM), which is a form of neural network that has the capacity to learn dependencies between input and output data. The FLASH model is thus able to utilize 24 hours of data to predict 15 minutes or an hour into the future.
* **Term 3 (Proposed Term):** 2020 Summer (GSFC) – Ellicott City Disasters III
	+ With an advanced model generated and enhanced by previous terms, this term will connect the model to the Howard County’s current operational threat matrix. Integrating the existing threat matrix, the FLASH model, additional spatially-distributed driver variables, and socioeconomic data, the third term will design a cumulative matrix in the form of an interactive tool that can be used by the partners. This tool will allow Howard County OEM to explore and assess potential flood risk quantitatively and spatially, which will empower informed decisions for the County’s early warning system. A virtual training on how to use the model output data in conjunction with the operational threat matrix will ensure that the end users can implement the tool effectively.

***Previous Terms:***

2020 Spring (GSFC) – Ellicott City Disasters II: Enhancing a Statistical Flood Risk Model to Improve Early Warning Systems and Public Safety

2019 Summer (GSFC) – Ellicott City Disasters: Applying NASA Resources to a Statistical Flood Risk Model to Improve Early Warning Systems and Public Safety

***Related DEVELOP Work:***

2018 Fall (MSFC) – Ohio River Valley Transportation & Infrastructure: Utilizing Synthetic Aperture Radar and NASA Earth Observations to Identify Optimal Transportation Routes to Assist Emergency Responders after Flood Events in the Ohio River Valley

2018 Summer (AL) – New Orleans Urban Development: Utilizing Earth Observations to Assist Groundwork New Orleans to Reduce Flood Vulnerability in New Orleans, Louisiana, Metropolitan Area

2018 Spring (ID) – Navajo National Monument Water Resources: Monitoring and Forecasting Precipitation Patterns and Erosion Potential to Enhance Archaeological Preservation and Decision Making

2017 Spring (MSFC) – Mississippi River Basin Disasters II: Automated Mapping of Flood Events in the Mississippi River Basin Utilizing NASA Earth Observations

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