**NASA DEVELOP National Program**

**2019 Spring Project Proposal**

**Arizona – Tempe**

**Lake Ontario Disasters**

*Employing NASA Earth Observations in the Greater Toronto Area to Improve Flood Preparedness for Coastal Communities*

**Project Overview**

***Project Synopsis*:** In the spring of 2017, constant record-breaking rainfall, rapid snowmelt, and high water levels in the Great Lakes region led to the flooding of hundreds of private properties and public infrastructure around Lake Ontario. Partnering with the Great Lakes and St. Lawrence Cities Initiative, City of Mississauga, City of Toronto, and the University of Michigan, the team will examine the environmental variables contributing to flooding in the Lake Ontario watershed for the Greater Toronto Area (GTA), Canada. The project objectives include assessing precipitation totals, topography, and soil moisture to generate a flood extent time series analysis of flood events. Remotely-sensed data will be compared to output from the Weather Research and Forecasting Model used by the University of Michigan. This project will use GPM IMERG, Landsat 8 OLI, Terra MODIS, Aqua MODIS, SRTM, SMAP, and Sentinel-1 C-SAR data. Additionally, the team will provide a tool to create maps of potential flood extent so partners can identify early flood warning signs.

***Community Concern:*** In 2017, Lake Ontario water levels were abnormally high, leading to massive flooding events along the shores of Lake Ontario and the St. Lawrence River, an outflow of the lake. Over $13 million was granted by the Canadian Red Cross for flood relief efforts in the first three months post-flood. While the 2017 flooding was unavoidable, the International Lake Ontario - St. Lawrence River Board wants to investigate the hydroclimate conditions contributing to flooding to better inform river flow decisions and better equip communities vulnerable to flooding. Flooding events are costly as they damage infrastructure and hinder economic activity. They also pose public health and safety concerns as standing water can host diseases and lead to unsafe conditions on the road. This work is important to the community so they can better forecast potential flooding to limit these costs.

***Source of Project Idea:*** This project idea came from Melissa Soline with the Great Lakes and St. Lawrence Cities Initiative (GLSLCI), who has partnered with DEVELOP since 2008 on various projects. She met Lance Watkins at the 2018 GLSLCI Annual Meeting and expressed interest in another DEVELOP project. Melissa Soline works with over 130 United States and Canadian mayors in the GLSLCI network, and she proposed a flood forecasting project to Arizona – Tempe and Massachusetts – Boston node leadership. Subsequently, she requested to focus on cities impacted near Lake Ontario.

***National Application Areas Addressed:*** Disasters, Water Resources

***Study Location:*** Lake Ontario Watershed, greater Toronto area, Canada

***Study Period:*** January 2015 – January 2019

***Advisors:*** Dr. David Hondula (Arizona State University), Dr. Cedric Fichot (Boston University)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Great Lakes and St. Lawrence Cities Initiative** | Melissa Soline, Program Manager US | End User | Yes |
| **City of Mississauga, Community Services Department, Environment Division** | Teresa Chan, Climate Change Specialist; Samer Inchasi, Works Maintenance Manager; Teresa Burgess-Ogilvie, Emergency Management Manager; Muneef Ahmad, Capital Project Manager; James Silburn, Geospatial Solutions Manager | End User | Yes |
| **City of Toronto, Office of Emergency Management** | Garrett Christie, Coordinator;  Tyler Griffin, Manager;  Maria Yung, Research Analyst | End User | Yes |
| **University of Michigan** | Dr. Drew Gronewold, Associate Professor | Collaborator | Yes |

***End-User Overview***

***End User’s Current Decision-Making Process:***The GLSLCI represents more than 130 US and Canadian mayors and municipalities working to advance the protection and restoration of the Great Lakes and St. Lawrence River. As a coalition of mayors and municipalities, the Cities Initiative is in a unique position to understand and help implement solutions to the challenges and issues affecting municipalities on the Great Lakes and St. Lawrence River. Policy and programmatic work are within the jurisdiction of the Cities Initiative Board, which is comprised of eight US and eight Canadian mayors. The organization recently completed a strategic planning process, via member input, that identified three main water priorities: climate change (including adaptation, mitigation, and building resilience), water quality/quantity, and water/wastewater infrastructure. The City of Mississauga uses static maps and GIS for its decision making on storm drainage, and the City of Toronto is working on driving its research initiatives in hazard identification since they help in preparing municipalities for an emergency.

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

*Great Lakes and St. Lawrence Cities Initiative* – The organization has little to no experience using Earth observations with regard to flooding.

*City of Mississauga, Community Services Department, Environment Division* – The City of Mississauga, Community Services Department, Environment Division has little to no experience using Earth observations with regard to flooding.

*City of Toronto, Office of Emergency Management* – The City of Toronto, Office of Emergency Management is not familiar with NASA Earth observations and does not currently use remote sensing data for decision making purposes.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*University of Michigan –* Dr. Drew Gronewold is the point of contact for the Weather Research and Forecasting (WRF) model and is available to offer support and insight to the team. He can run the model for the team, and he is also interested in the team’s end products to see the utilization of NASA Earth observation data.

***Dissemination by Boundary Organizations*:**

*Great Lakes and St. Lawrence Cities Initiative –* Melissa Soline plans to distribute the project results directly to the mayors and municipal staff that are members of the GLSLCI, particularly to member cities that also face flooding issues. In addition, the results will likely be presented at the 2019 Great Lakes and St. Lawrence Cities Initiative Annual Meeting that many of the GLSLCI mayors attend.

*University of Michigan* – Dr. Drew Gronewold is currently building a model that can simulate the 2017 Lake Ontario flooding, and through his efforts to incorporate products from this DEVELOP project in the model, the project products will eventually be disseminated to hydrologists using the model and other stakeholders, including the United States Army Corps of Engineers and Environment, Great Lakes Integrated Sciences and Assessments, and Climate Change Canada.

*City of Toronto, Office of Emergency Management* – Results would be incorporated into the City's Hazard Identification and Risk Assessment (HIRA), the final version of which may be shared internally to other City Divisions for emergency planning and mitigation purposes. Externally, results and methodologies may be shared with York University, who is assisting them with HIRA research initiatives, as well as with the Toronto Region Conservation Authority, a key partner in flood-specific emergency planning and response.

*City of Mississauga, Community Services Department, Environment Division* – The City is planning on sharing the project results with the Credit Valley Conservation (CVC) Authority, City of Brampton, City of Caledon, and the Region of Peel. Together they are seeking to identify flood risks as well as learn lessons from their experiences with ice jams and thunderstorms and the gaps and risks associated with them.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will communicate with the partners on a biweekly basis by email or teleconference to inform the partners of the status of the project. The main POC will be the Project Lead for the entire term, while the Center Lead will help facilitate the first communication at the beginning of the term. The meetings will be scheduled and coordinated with the Massachusetts – Boston node to plan a call with the common partners when possible.

***Transition Plan*:** A handoff at the end of the term will be conducted virtually using WebEx or Google Hangouts to run through the results and tutorial (if applicable) so the partners can replicate the project work at their own convenience. Partners will be invited to remotely join the end of term closeout to watch the team’s presentation. All processed data products and end products will be sent to the partners by NASA Large File Transfer. Software release is anticipated and the partner will be notified once the tool is available on GitHub.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **GPM IMERG** | Precipitation | Global Precipitation Measurement data will be used to quantify precipitation in the Lake Ontario drainage basin leading up to the 2017 flooding event. |
| **Sentinel-1 C-SAR** | Ground range detection | Ground range detection will be used to determine flooding extent. |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance will be used to determine  flooding extent and snow cover. This dataset will be used for providing a higher spatial resolution alternative to MODIS where cloud free images exist. |
| **Aqua MODIS** | Surface reflectance | Surface reflectance will be used to determine snow cover extent. |
| **Terra MODIS** | Surface reflectance | Surface reflectance will be used to determine snow cover extent. |
| **SRTM** | Digital elevation model | The digital elevation model will be used to both understand and predict flooding extent in terms of land topography. |
| **SMAP** | Soil moisture | Soil moisture measurements will be used to understand soil porosity. |

***Ancillary Datasets:***

International Lake Ontario - St. Lawrence Regulation Board & Water Levels – To compare remotely-sensed flood extent to water levels in the Lake Ontario - St. Lawrence system

International Lake Ontario - St. Lawrence Regulation Board & Lake Ontario Outflow Charges – To incorporate into outflow/inflow from the Moses-Saunders Dam calculations for each section of the Lake Ontario - St. Lawrence water system

USGS & Great Lakes and Watersheds Shapefile – To establish the study area and extent of the Lake Ontario drainage basin

***Modeling:***

Weather Research and Forecasting (WRF) model (POC: Dr. Drew Gronewold, University of Michigan)

***Software & Scripting:***

Esri ArcGIS – Data processing and image and map creation

R – Data processing and statistical analysis

Google Earth Engine API – Data processing and flood basin observation tool development

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Snow Ice Cover, Precipitation, & Soil Moisture Time Series** | The partners will use this time series to identify how snow cover, precipitation, and soil moisture have changed from 2017 to 2019. They will be able to see areas that experienced an increase or decrease in precipitation and see if snowmelt may increase the water balance. This will allow the partners to target and forecast areas that may experience flooding. | GPM IMERG, Landsat 8 OLI, Sentinel-1 C-SAR, Aqua MODIS, Terra MODIS, SRTM, and SMAP data will be combined with ancillary datasets to assess snow cover, precipitation, and soil moisture. R will be used to identify spatiotemporal trends that could lead to flooding. | I |
| **Google Earth Engine Lake Ontario Watershed Conditions Tool** | As a means of enhancing partners’ understanding of historical and current hydrological cycles, this Google Earth Engine tool would create charts and maps of flood conditions and flood extent during the desired water years. | The Google Earth Engine Lake Ontario Watershed Conditions Tool will use GPM IMERG, Landsat 8 OLI, Sentinel-1 C-SAR, Aqua MODIS, Terra MODIS, SRTM, and SMAP data to create a data-driven approach to understand flood events and identify early warning signs. | IV |
| **Modeled Flood Extent Map** | The partners will use the modeled flood map to bring awareness to their member cities of the areas that may become flooded. | The WRF model will be used to assess the water balance and forecast flood extent. GPM IMERG, Landsat 8 OLI, Sentinel-1 C-SAR, Aqua MODIS, Terra MODIS, SRTM, and SMAP data are possible inputs to add to the model, which the team will provide to the partner at the University of Michigan to run. | I |

***End-User Benefit*:** Flooding is an issue for all of the Great Lakes and St. Lawrence municipalities, and they are actively looking for data and information that can aid in their flood preparation and mitigation efforts. Using NASA Earth observations to monitor and observe winter conditions and flood extent would help them better prepare information to distribute to at-risk communities. The products will help inform the partners about the environmental parameters that contribute to flooding that, in turn, could help their member municipalities better prepare for more extreme weather and other expected impacts.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2019 Spring

***Related DEVELOP Work:***

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

2017 Spring (MSFC) – Mississippi River Basin Disasters II: Utilizing NASA Earth Observations to Create an Automated Flood Probability Map in the Mississippi River Basin

2015 Spring (IRI) – Malawi & Botswana Disasters: Creating a Flood Forecasting Tool Derived from NASA Earth Observations and Based on Flood Definitions

**Notes & References:**

***Notes*:**

* Because GLSLCI personnel work closely with the mayors in their network, they will work closely on this project to ensure that the needs from the mayors are being met. The GLSLCI will provide leveraged support by gaining access to ancillary data, such as dam outflow from Canada, which may be required for the successful completion of this project.
* This project has similar objectives with the New York Disasters project at the Massachusetts – Boston node, so it is planned that both teams will work closely and collaborate on some of the end-products, such as the flood extent maps, the story map, and the Google Earth Engine tool.
* The team will be providing the input data to Dr. Drew Gronewold who will run the WRF model for the team. The team will use the modeled flood extent to see if the outputs from the GEE tool are similar to the model’s output.

***References:***

Bechard, G., Durrett, S., Aubry-Morin, J., Brown, T., Clavet, P., Campany, R., … Sciremammano, F. (2018). *Observed conditions and regulated outflows in 2017* (Report prepared for the International Lake Ontario St. Lawrence River Board). Retrieved from http://ijc.org/files/tinymce/uploaded/ISLRBC/ILOSLRB\_SummaryReport.pdf

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Federal Emergency Management Agency. (2017). *New York Flooding (DR-4348).* Retrieved from https://www.fema.gov/disaster/4348