**Lake Ontario Disasters**

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

**VPS Title:** Hold Back the Flow: Flood Monitoring in the Greater Toronto Area

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:*** The Greater Toronto Area (GTA), home to over 6.4 million people, has experienced severe flooding over the past ten years. Driven by a partnership with the City of Toronto, the City of Mississauga, the Great Lakes and St. Lawrence Cities Initiative (GLSLCI), the Credit Valley Conservation (CVC), and the Toronto and Region Conservation Authority (TRCA), this project used remotely sensed data from NASA Earth observations to analyze the hydroclimatic and topographic variables that contributed to past floods. The results of this project provided Toronto area municipalities with tools to identify early warning signs of and inform responses to flood threats.

***Abstract:***

From late January through the beginning of May 2017, an extraordinary amount of precipitation fell in the Lake Ontario watershed. By late April, large swaths of the Greater Toronto Area (GTA), including numerous lakefront properties, beaches, and public recreation facilities, had become inundated with water. Partnering with the City of Toronto, the City of Mississauga, the Great Lakes and St. Lawrence Cities Initiative (GLSLCI), the Credit Valley Conservation (CVC), and the Toronto and Region Conservation Authority (TRCA), this project provided tools for local and regional organizations to improve their response to flood events. These tools used Earth observations from six satellites to produce two end products. Sentinel-1 C-Band Synthetic-Aperture Radar (C-SAR) and Sentinel-2 Multispectral Instrument (MSI) provided data for flood extent maps using a classification algorithm. Global Precipitation Measurement (GPM) Integrated Multi-Satellite Retrievals for GPM (IMERG), Soil Moisture Active Passive (SMAP) L-band Radiometer, Terra Moderate Resolution Imaging Spectrometer (MODIS), and Shuttle Radar Topography Mission (SRTM) contributed precipitation, soil moisture, snow cover, and elevation data used in a Google Earth Engine (GEE) data visualization tool. The results of this project demonstrated the feasibility of GEE as a platform for providing municipalities in the Toronto metropolitan area with tools to understand and visualize flood behavior and associated patterns in hydroclimatic variables. Thus, these municipalities are better prepared to protect the most vulnerable flood-prone areas in the GTA.

**Keywords:**

flooding, Google Earth Engine (GEE), GPM IMERG, MODIS, SMAP, remote sensing, Sentinel-1 C-SAR

***National Application Area Addressed:*** Disasters

***Study Location:*** The Great Lakes Watershed bordered by IL, IN, MI, MN, NY, OH, PA, & WI in the United States; Canada

***Study Period:*** March 2000 to March 2019

***Community Concerns:***

* Severe flooding in the spring of 2017 damaged properties along Lake Ontario, threatening property owners, recreational boaters, and shoreline businesses while also impacting tourism throughout the region.
* The Toronto Islands experienced particularly notable impacts during the spring 2017 flooding events, with the Toronto Island Park closing for 88 days.
* A major flood event in July of 2013 caused extensive damage to private properties and public infrastructure, cutting power to roughly 300,000 residents. This resulted in $940 million in insured property losses and cost the municipal government over $65 million for response and recovery efforts.
* Flooding is known to pose a serious public health risk, hinder economic activity, and inundate large swaths of the metropolitan area.

***Project Objectives:***

* Create a flood extent map for the Toronto Area
* Analyze trends in precipitation, snow cover, and soil moisture
* Provide our partners with data to understand historical flooding events

**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, Environmental 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 |
| **Credit Valley Conservation** | Christine Zimmer, Senior Manager | End User | No |
| **Toronto and Region Conservation Authority** | Victoria Kramkowski, Government and Community Relations Specialist | End User | No |

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

The City of Toronto OEM uses expertise and reports from local water conservation authorities and drives research initiatives in hazard identification to help prepare for an emergency. During the flooding of 2017, city employees manually measured water levels in the field to monitor flood levels. The City of Mississauga uses static maps and GIS to make decisions regarding storm drainage but does not have a data-driven approach to disaster planning and management. The GLSLCI uses research and expertise on the policy side of planning to inform disaster management. The CVC and the TRCA monitor current watershed conditions and weather forecasts, predict river and creek conditions, and communicate their findings to the public, municipalities, and media.

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

Flooding is a constant issue for municipalities along the Lake Ontario shoreline. The produced flood extent maps offer insight on areas particularly vulnerable to flooding and show the change in flood extent as flood conditions persist. The GEE graphical user interface provides the end users with a tool to visualize variables that contributed to past flooding and may contribute to future flooding. The informational video enables broader dissemination of project outcomes and flooding awareness in the GTA. These products can help municipalities make informed decisions and better prepare for future flood events.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Sentinel-1 C-SAR** | Ground range detection | Ground range detection was used to determine flood extent. |
| **Sentinel-2 MSI** | Surface reflectance | Surface reflectance was used to determine flood extent. |
| **GPM IMERG** | Precipitation | GPM IMERG data were used to quantify precipitation in the Lake Ontario drainage basin leading up to past flood events. |
| **SRTM** | Digital elevation model | The digital elevation model was used to understand and predict flood extent in terms of land topography. |
| **SMAP L-band Radiometer** | Soil moisture | Surface soil moisture measurements were used to understand soil porosity and saturation. |
| **Terra MODIS** | Surface reflectance, Normalized Difference Snow Index (NDSI) | Surface reflectance was used to determine NDSI in order to map snow cover. |

***Ancillary Datasets:***

* GeoGratis: Canadian Government Digital Elevation Model – Elevation data to identify flood-prone low-elevation areas
* United States Geological Survey (USGS) & Great Lakes and Watersheds Shapefile – Established the study area and extent of the Lake Ontario drainage basin

***Software & Scripting:***

* Esri ArcMap – Processing of study area shapefiles
* Google Earth Engine API – Processing imagery, developing data visualization tool, and classifying surface type
* R – Variable selection for flood mapping

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Flood Extent Maps** | Sentinel-1 C-SAR  Sentinel-2 MSI | The partners can use flood maps to bring awareness to areas that are vulnerable to inundation. | I |
| **Flooding in the Lake Ontario Watershed (FLOW) Visualization Tool** | GPM IMERG  SMAP L-band Radiometer  SRTM  Terra MODIS | The partners can use this user-friendly graphical user interface to visualize and examine elevation, precipitation, soil moisture, and snow cover from 2000 to 2019. | IV |

**Project Handoff Package**

*Transition Plan:* At the end of the term, the team sent a handoff package to partners through email and NASA Large File Transfer (LFT). The team also conducted a meeting with project partners to present and explain how to use the end products.

*Software Release Plan*: The GEE Flooding in the Lake Ontario Watershed (FLOW) Visualization Tool falls under Software Release Category IV. The code and associated instructional materials were released to the partners after the completion of the Software Release Process. The team had communicated this to project partners and end users in advance, and they were aware of the delay in receiving access to the GEE GLOW Visualization Tool.

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**Handoff Package:**

* Presentation
* Technical Paper
* Project Video
* Shapefiles
* Flood Extent Maps

**References:**

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