**Northern Great Plains Disasters**

*Using Earth Observations to Enhance Flood Monitoring on Tribal Lands in the Northern Great Plains*

**Project Team**

***Project Team:***

Anna Ballasiotes (Project Lead)

Susan Lamb

Liana Solis

Remington Zeppelin

***Advisors & Mentors:***

Dr. Juan Torres-Perez (Biospheric Branch, Earth Science Division, NASA Ames Research Center)

Dr. Cindy Schmidt (Indigenous Peoples Initiative, NASA Ames Research Center)

Dr. Amber Jean McCullum (Indigenous Peoples Initiative, NASA Ames Research Center)

***Team POC:*** Anna Ballasiotes, annaballasiotes@gmail.com

***Software Release POC:*** Liana Solis, lianadsolis@gmail.com

***Partner POC:*** Syed Huq, shuq@sicangu.com and James Rattling Leaf, jamesrl413@gmail.com

**Project Overview**

***Project Synopsis:***

The Northern Great Plains have experienced an increase in catastrophic flooding events in the last 50-70 years, including a devasting flood in 2019 that resulted from record precipitation. We partnered with the Rosebud Sioux Tribe Water Resources Office, the Great Plains Tribal Water Alliance (GPTWA), and the NASA Capacity Building Program’s Indigenous Peoples Initiative to map historical flood events and flood risk factors on tribal lands in the Northern Great Plains. In addition, we developed a tool for mapping flood extent using remote sensing data that our partners can use and adapt to support their current flood mitigation approaches.

***Abstract:***

In 2019, the Great Plains experienced unprecedented catastrophic flooding. Large flood events are predicted to increase in frequency and severity, posing risks to communities in this region, particularly Tribal Nations. We used Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), imagery from the Sentinel-2 MultiSpectral Instrument (MSI), and digital elevation models from the Shuttle Radar Topography Mission (SRTM) within Google Earth Engine to map historical floods in the region beginning in 2014 with particular attention to the Rosebud Sioux Reservation and the tribal lands of other Great Plains Tribal Water Alliance members. This historical mapping used C-SAR for a combined method approach with a Z-score algorithm in addition to an index for flooded short vegetation. We also developed a flood risk map by weighting different flood predictor variables according to flood risk literature. These variables included soil drainage from the Soil Survey Geographic Database (SSURGO); elevation, slope, and Topographic Wetness Index (TWI) derived from digital elevation models; precipitation from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS); land cover from the National Land Cover Database (NLDC); and Normalized Difference Vegetation Index (NDVI) derived from Landsat 8 Operational Land Imager (OLI). From the flood extent and risk maps, we identified widespread flooding in short vegetation (including cropland) and noted flood susceptibility in regions exhibiting high social vulnerability and low community resilience (FEMA indices). We created an ArcGIS Online StoryMap to share project background, results, and data. Additionally, we provided a written tutorial so partners may replicate the flood mapping for future flood events.

***Key Terms:***

Sentinel-1, SAR, remote sensing, flood risk, Google Earth Engine, tribal lands

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

***Study Location:*** Northern Great Plains (ND, SD, NE)

***Study Period:*** April 2014 – December 2020

***Community Concerns:***

* Increased flooding on the Northern Great Plains over past decades has restricted community access to essential services and has caused extensive damage to infrastructure and agriculture.
* The Rosebud Sioux Tribe and the GPTWA seek to incorporate remote sensing data and tools in tribal flood mitigation efforts.
* Air moisture in the region is expected to increase as temperature increases, leading to higher frequency and severity of precipitation and, subsequently, flooding – further emphasizing a need for flood risk management tools.

***Project Objectives:***

* Generate historical flood mapping tool focused on the Northern Great Plains to help partners identify the extent of past flood events and track the extent of future flood events
* Create a tutorial that guides end-users in creating a flood map after a flood event
* Map flood risk over the Northern Great Plains region, with specific focus on tribal lands of GPTWA members, to help partners identify areas most exposed to flood vulnerability and hazard
* Communicate background information regarding study region and project partners, identify community need for flood mapping tools and flood risk assessment, and provide interactive displays of project deliverables to partners and the general public using ArcGIS StoryMap

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Rosebud Sioux Tribe, Water Resources Office** | Syed Huq, Director | End User | No |
| **Great Plains Tribal Water Alliance** | James Rattling Leaf, Sr., Climate Partnerships Coordinator | End User | No |
| **Federal Emergency Management Agency, Region VIII Mitigation Division**  | Jamie Prochno, Civil Engineer; Margaret Doherty, Risk MAP Program Specialist | End User | No |
| **NASA Indigenous Peoples Initiative** | Dr. Cindy Schmidt, Research Scientist; Dr. Amber Jean McCullum, Research Scientist | Collaborator | No |

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

The Rosebud Sioux Tribe Water Resources Office is responsible for disaster management plans for environmental problems such as drought and floods. It currently utilizes collected surface water and groundwater measurements as well as remote sensing data to monitor and manage water resources on tribal land. The Water Resources Office is looking to increase its capacity to map flood risk both in data acquisition and use of mapping software. The Rosebud Sioux Tribe along with the Flandreau Santee Sioux Tribe, Oglala Sioux Tribe, and Standing Rock Sioux Tribe, are members of the Great Plains Tribal Water Alliance (GPTWA). This group provides public education, outreach, and research on water science and policy in the Missouri River Basin. The GPTWA also seeks to expand its use of geospatial data and tools through capacity-building opportunities between NASA and their communities.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Sentinel-1 C-SAR** | Backscatter, Normalized Difference Flood Index (NDFI), Normalized Difference Vegetated Flood Index (NDVFI) | Used to identify inundation due to flooding for use investigation of historical trends in flooding. |
| **SRTM** | Digital Elevation Model (DEM) | Used to identify the study area topography and delineate watersheds. |
| **Sentinel-2 MSI** | Irradiance/Reflectance | Used to verify flood extent.  |
| **Landsat 8 OLI** | Surface Reflectance, Normalized Difference Water Index (NDWI) | Used to map flood extent and provide a baseline comparison for years in which flooding events did not occur. |

***Ancillary Datasets:***

* USGS Watershed Boundary Dataset (WBD) – Used to understand where water drains within the study area.
* USGS National Hydrography Dataset (NHD) – Used to understand river systems and to help validate the risk map within the study area.
* USGS National Land Cover Database (NLCD) – Used to identify types of landcover that face flood impacts or contribute to flooding.
* USDA Soil Survey Geographic Database (SSURGO) – Used to identify soil types and assess how the soil type affects water drainage.
* Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) – Used to estimate the amount of precipitation over the study region for use in the flood risk map.
* FEMA National Risk Index Layer – Used to assess community vulnerability to flooding
* European Commission GHSL: Global Human Settlement Layers, Population – Used to estimate how many people were impacted by flooding.
* USGS/ NASA Terra and Aqua combined Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type Version 6 – Used to estimate the agricultural land affected by flooding.
* European Commission's Joint Research Centre (JRC) Global Surface Water (GSW) v1.2 – Used within the s1flood script to check for permanent open water and seasonal inundation.
* USGS Dynamic Surface Water Extent (DSWE) – Used with the JRS-GSW within the s1flood script to check for permanent open water and seasonal inundation.

***Software & Scripting:***

* Google Earth Engine – Used to obtain datasets and identify historical inundation
* ESRI ArcGIS Pro 2.5.2 – Used for data processing and making flood risk maps

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **FLood Observation and Analysis Tool (FLOAT)** | Sentinel-1 C-SAR, SRTM, Sentinel-2 MSI | This tool will allow partners to replicate the team’s methods and map future flood events using satellite imagery within GEE. | III |
| **Historical Flood Map** | Sentinel-1 C-SAR, SRTM, Sentinel-2 MSI | Partners can use the historical flood maps to determine which land areas were affected most during past flood events and to assess where to focus flood mitigation techniques.  | III |
| **Historical Flood Mapping Tutorial** | N/A | This tutorial will familiarize users with GEE and instruct them on how to update the historical flood map after future flood events have taken place.  | III |
| **Flood Risk Assessment Map** | SRTM, Landsat 8 OLI | The flood risk assessment map considers causative factors (e.g., soil moisture, topography, precipitation trends, etc.) and will aid partners in determining where to focus flood mitigation techniques.  | N/A |
| **ArcGIS StoryMap** | Sentinel-1 C-SAR, SRTM, Landsat 8 OLI, Sentinel-2 MSI | The ArcGIS StoryMap will help the community share their story and raise awareness regarding flood risk, damage, and response. It also provides interactive displays of the historic flood and risk maps, providing examples of how remote sensing tools can inform and prepare communities for flood disasters. | N/A |

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

The Rosebud Sioux Tribe Water Resources Office and the GPTWA can use the flood risk and historical flood maps to inform decision-making on flood management and mitigation. The tutorial will enable the end-user to independently update the historical flood tool while building upon their current knowledge of remote sensing and its applications as well as help anticipate flood extent. Lastly, the ArcGIS StoryMap will provide general information concerning inundation in the Northern Great Plains region to inform and raise awareness for flood risk, damage, and response. Overall, the results of this project will increase the Rosebud Sioux Tribe Water Resources Office’s and GPTWA’s remote sensing capacity while supporting tribal decision-making by supplying relevant resources.

**References**

Almukhtar, S., Migliozzi, B., Schwartz, J., & Williams, J. (2019, September 11). The Great Flood of 2019: A Complete Picture of a Slow-Motion Disaster. *The New York Times*. Retrieved from <https://www.nytimes.com/interactive/2019/09/11/us/midwest-flooding.html>

Cian, F., Marconcini, M., & Ceccato, P. (2018). Normalized Difference Flood Index for rapid mapping: Taking advantage of EO big data. R*emote Sensing of Environment, 209C,* 712-730. doi: 10.1016/j.rse.2018.03.006.

DeVries, B., Huang, C., Armston, J., Huang, W., Jones, J. W., & Lang, M. W. (2020). Rapid and robust monitoring of flood events using Sentinel-1 and Landsat data on the Google Earth Engine. *Remote Sensing of Environment*, *240*, 111664. doi: 10.106/j.rse.2020.111664

Neri, A., Villarini, G., & Napolitano, F. (2019). Statistically-based projected changes in the frequency of flood events across the U.S. Midwest. *Journal of Hydrology*, 124314. doi: 10.1016/j.jhydrol.2019.124314