**Central California Disasters**

*Incorporating Satellite-Derived Precipitation and Soil Moisture Products into Flood Preparedness and Emergency Management in California*

**Project Team**

***Project Team:***

Abhinav Banthiya (Project Lead)

Chanice Brown

Jan Hery

Shagun Sengupta

***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

Dr. Xia Cai (NASA Langley Research Center)

Dr. Venkataraman Lakshmi (University of Virginia)

***Node Lead:***

Isabel Lubitz (Maryland – Goddard)

***Team Contact:*** Abhinav Banthiya, ab5472@columbia.edu

***Partner Contact:*** Dr. MD Haque, md.haque@water.ca.gov

**Project Overview**

***Project Synopsis:***

California saw major storms and rainfall caused by multiple atmospheric rivers in late 2022 through early 2023. Major flooding due to these storms lead to 22 lives lost and 4.6 billion dollars in property damage. This project partnered with the California Department of Water Resources (CA DWR) to assess the utility of satellite data for monitoring precipitation and soil moisture to fill in data gaps for improved risk assessments in Central California, using the 2022 – 2023 flooding events in the Salinas Valley Watershed as a use case for the potential utility of these data to inform flooding preparedness and emergency management efforts.

***Abstract:***

Atmospheric rivers are a major contributor to extreme precipitation events and flooding in California. This study assessed the feasibility of using Earth observation data to monitor precipitation, soil moisture, and flooding from atmospheric rivers in the Salinas River Watershed in central California during the winter of 2022 – 2023. The team analyzed satellite derived precipitation estimates from the Global Precipitation Measurement mission, soil moisture data from the Soil Moisture Active Passive radiometer, and synthetic aperture radar imagery from Sentinel-1 to detect flood inundation. Global Precipitation Measurement precipitation estimates were found to underestimate rainfall by 33% to 52% compared to rain gauge data. The team found the Soil Moisture Active Passive dataset to be a valuable flooding indicator that they could visualize through various graphical representations, although its accuracy still needs verification with in-situ flood maps. Sentinel-1 synthetic aperture radar imagery provided mapping of flood inundation extent along the Salinas River and surrounding areas and the Blue Spot model appears to be a good predictor of pluvial flood zones. The findings suggest Earth observations can enhance precipitation and flooding monitoring by the California Department of Water Resources, though further verification is needed. Integration of these datasets with vulnerability indices highlighted communities at highest risk during the 2022-2023 flooding events.

***Key Terms:***

California atmospheric rivers, pluvial flooding, earth observations, GPM IMERG, SMAP, Sentinel-1, C-SAR, Precipitation, Soil Moisture, Community Vulnerability

***Application Area:*** Disasters

***Study Location:*** Salinas Valley Watershed, California

***Study Period:*** November 2022 to April 2023

***Community Concerns:***.

* Flooding can have significant economic consequences, including loss of productivity, decreased tourism revenue, increased insurance premiums, and reduced property tax revenues, increasing financial strains on affected communities.
* Flooding can cause extensive damage to homes, businesses, and infrastructure, leading to financial losses for individuals and communities.
* Flooding poses immediate dangers to public safety, including the risk of drowning, and injuries, while also exposing communities to health hazards such as contaminated water, waterborne diseases, mold growth, and other illnesses.
* Floods can damage critical infrastructure such as roads, bridges, power lines, and water treatment facilities, disrupting essential services and hindering emergency response efforts.

***Project Objectives:***

* Use GPM IMERG late run V06 and Final Run V07 data to assess the feasibility of using satellite precipitation measurements in areas with sparse ground observations.
* Review spatial trends of soil moisture to identify flood prone areas.
* Identify flooding extent in Salinas Watershed across the study period to identify locations in the valley susceptible to flooding.
* Input factors related to flooding and calculate risk at the neighborhood level.

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization(s)** | **Contact (Name, Position/Title)** | **Partner Type** | **Sector** |
| **California Department of Water Resources**  | Dr. Mike Anderson, California State Climatologist; Dr. MD Haque, Senior Engineer & Supervising Engineer/Manager Risk Assessment and Mapping Program   | End User  | State Government |

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

The CA DWR is interested in improving their risk assessments for water on the ground. They utilize models from the United States Army Corps of Engineers for basin-scale in some areas with some areas having no data. They have explored the use of some Sentinel-1 C-SAR data but due to temporal limitations have not implemented that widely. Satellite precipitation and soil moisture measurements are of interest as not all areas have in situ data or specialized models.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **GPM IMERG** | Precipitation  | The team used GPM data to measure rainfall and explore it as a possible data gap filler in areas with no rain gauges by measuring its accuracy and performance with respect to rain gauge. |
| **SMAP**  | Soil moisture  | In combination with GPM IMERG precipitation data, SMAP surface soil moisture characterized conditions associated with flooding. |
| **Sentinel-1 C-SAR**  | VH polarization / Standing water  | The team used SAR data to identify and map the extent of flooding. |
| **Landsat 8 OLI** | Surface reflectance | The team used Landsat data to identify land cover/land use within the watershed. |
| **Landsat 9 OLI-2** | Surface reflectance | The team used Landsat data to identify land cover/land use within the watershed. |

***Ancillary Datasets:***

* United States Geological Survey (USGS) Salinas River Watershed Boundary – Watershed boundary for defining the project study area
* USGS Salinas Valley Hydrologic Models – Surface Water Data - Stream network for the Salinas River in the lower and upper Salinas Valley Watershed
* USGS Lidar Point Cloud CA\_AZ\_FEMA\_R9\_Lidar\_2017\_D18 60251836 – Point cloud data for creating DEM of Bradley, California
* Esri Microsoft Building Footprints – Building data for Blue Spot modeling
* CDC/ATSDR Social Vulnerability Index– Index for identifying vulnerability within the watershed

***Models:***

* Blue Spot Model (POC: Chanice Brown, Kennesaw State University) – Predicting possible flood inundation sites

***Software & Coding Languages:***

* ArcGIS Pro (v3.1.2) – Data visualization, mapping, and site selection for analysis
* Python (v3.9.18 and v3.11.5) in Visual Studio Code – Data processing, timeseries analyses, geospatial analyses, statistical analyses, plot creation
* Google Earth Engine API – Generating and visualizing flood inundation

***End Product(s):***

|  |  |  |
| --- | --- | --- |
| **End Product(s)** | **Earth Observations Used**  | **Partner Benefit & Use** |
| **Soil Moisture – Methodology, Time Series and Saturation Map** | SMAP | This approach will equip partners with a comprehensive methodology and corresponding plots to harness saturated area information derived from space, facilitating the assessment of flooding impacts in this context. |
| **Precipitation – Statistical accuracy analysis, Spatial Plots**  | GPM IMERG | This statistical analysis will help partners decide whether satellite precipitation measurements can be used in their disaster response, especially for areas with sparse in-situ observations. |
| **Flood Inundation -****Spatial Plots, Change Detection** | Sentinel-1 C-SAR | These plots equip partners to identify standing water and can be used to make flood inundation plots, which can help identify flood-prone areas. |
| **Land Cover / Land Use Map** | Landsat 8 OLI, Landsat 9 OLI-2 | This product examines the land cover characteristics of the Salinas River Watershed to provide partners with a spatial assessment of environmental variables that can be used in conjunction with hydrological modeling techniques to identify an area’s level of flood susceptibility. |
| **Predicted Urban Flooding -****Spatial plot using Blue Spot Model** | N/A | These plots help partners to identify areas of potential spillover events, which can help inform flood risk management practices. |
| **Social Vulnerability with flood inundation – Spatial plot** | Sentinel-1 C-SAR | This plot helps partners identify census tracts that are vulnerable to floods with underlying Social Vulnerability Indices and can help inform management strategies. |

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

The developed end products will offer the CA DWR novel ways for monitoring flooding occurrences across central California and evaluating flood risk through the integration of remote sensing data. The team has showcased a diverse range of methodologies aimed at aiding the CA DWR in their comprehensive assessment of flooding events. These include detailed analyses of precipitation patterns, soil moisture dynamics, flood inundation mapping, and an urban flood model.

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