National Aeronautics and Space Administration

CENTRAL CALIFORNIA DISASTERS

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

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DEVELOP

Pop-Up Project | Spring 2024

TEAM INTRODUCTION

Shagun Sengupta

M.S. Geospatial Data Science

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M.S. Data Science

Abhinav Banthiya

M.A. Climate and Society

Chanice Brown

B.A. Geography

PARTNER

Image Credit: CA DWR, Sand boil 1997

California Department of Water Resources

- Manages California's water resources
- Performs duties like **Flood Preparedness** combined with **Emergency Management**
- Point of contact:
  - **Dr. Mike Anderson**, California State Climatologist
  - **Dr. MD Haque**, Senior Engineer & Supervising Engineer/Manager Risk Assessment

The CA DWR is interested in improving their risk assessments for water on the ground.

COMMUNITY CONCERNS

Image Credit: Steve Payer, Flooded American River Parkway in 2006

- Economic Impacts
- Property Damage and Loss
- Public Safety and Health Risks
- Infrastructure Damage

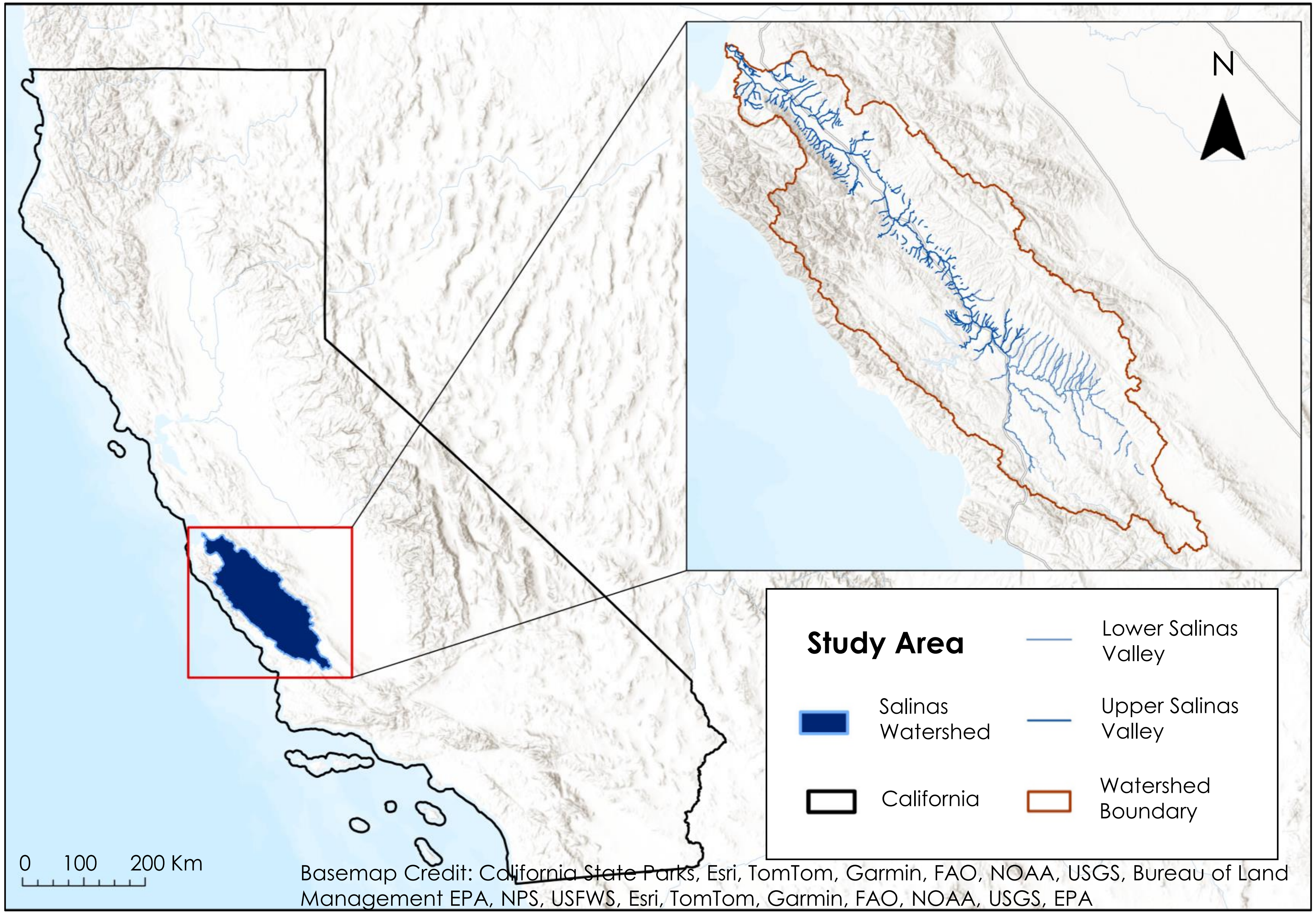
COMMUNITY CONCERNS

- **California** December 2022 to March 2023
  - Dozens of atmospheric rivers
  - 6 flooding events
  - Integrated water vapor transport (IVT) > 300% to 500% than normal
  - Highest percentages in the Central Valley
  - Over 200,000 buildings lost power
  - 6,000 evacuations

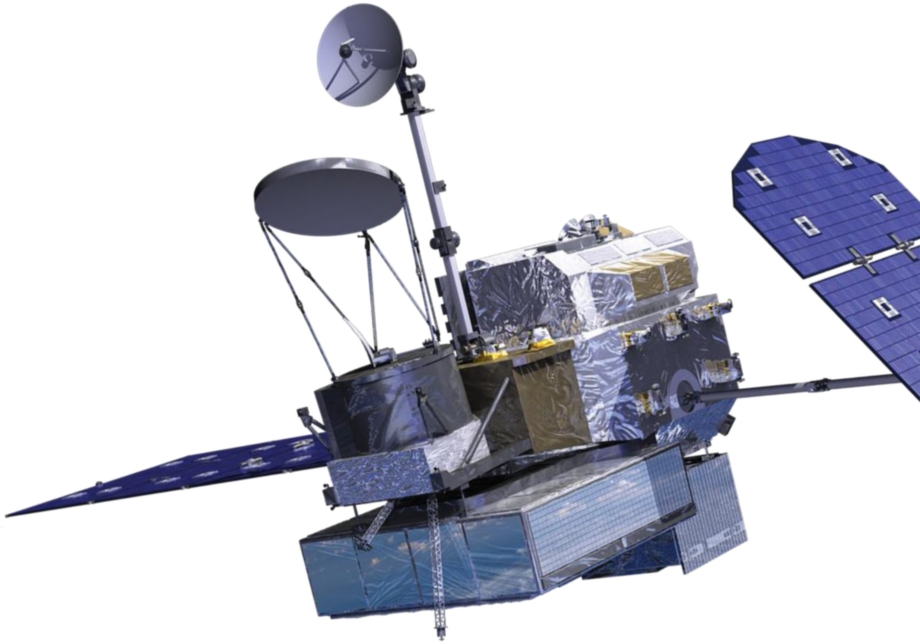
Image Credit: Kenneth James, repair work of levee breach on Deer Creek

PROJECT OVERVIEW

- **Study Area**
  - Central California
  - **Focus**: Salinas Valley Watershed
- **Study Period**
  - November 2022 – April 2023
  - At least 12 Atmospheric Rivers
- **Analysis Focus**
  - Precipitation
  - Soil Moisture
- **Case Study Focus**
  - Bradley, California
  - January 14th & March 10th



EARTH OBSERVATIONS (EO's)



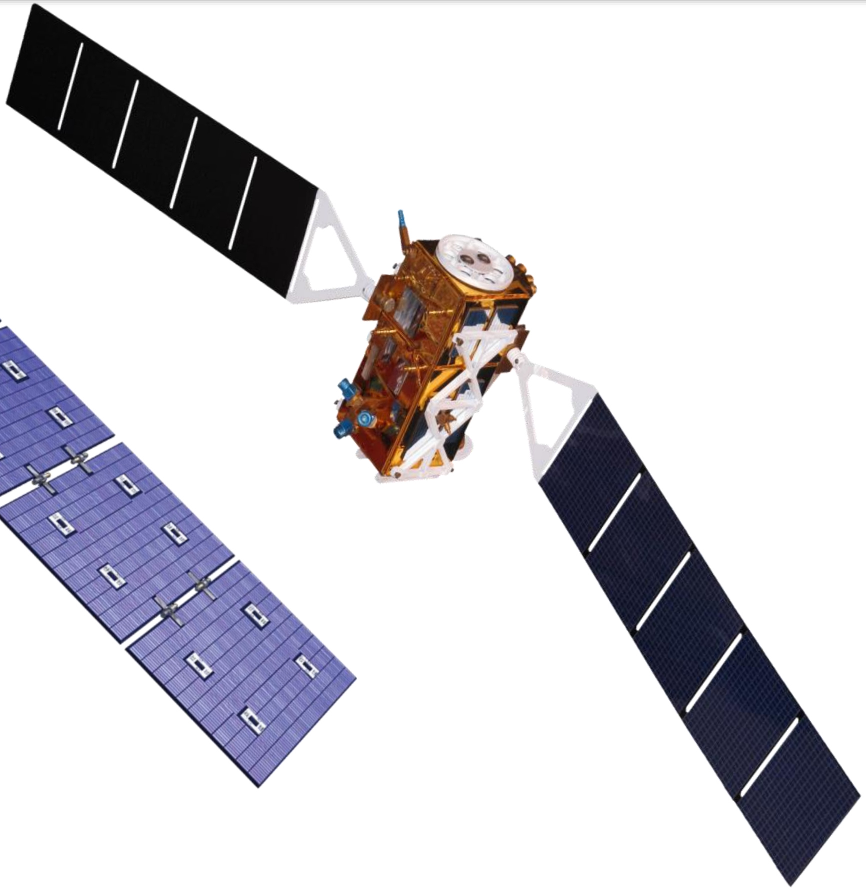


Image Credits: NASA, ESA

Global Precipitation Measurement Core Observatory (**GPM IMERG**)

Sentinel-1 C-Synthetic Aperture Radar (C-SAR)

Soil Moisture Active Passive (**SMAP**)

PROJECT FOCUS

What is the **goal** of this project?

- Incorporating NASA EO's of:
    - Precipitation
    - Soil Moisture
- Combined with:
    - Land Use
    - Flood Inundations
    - Urban Flood Risk Model (Blue-Spot)
    - Social Vulnerability Index

"Can NASA EOs help better assess **pluvial flooding** using GPM and SMAP data?"

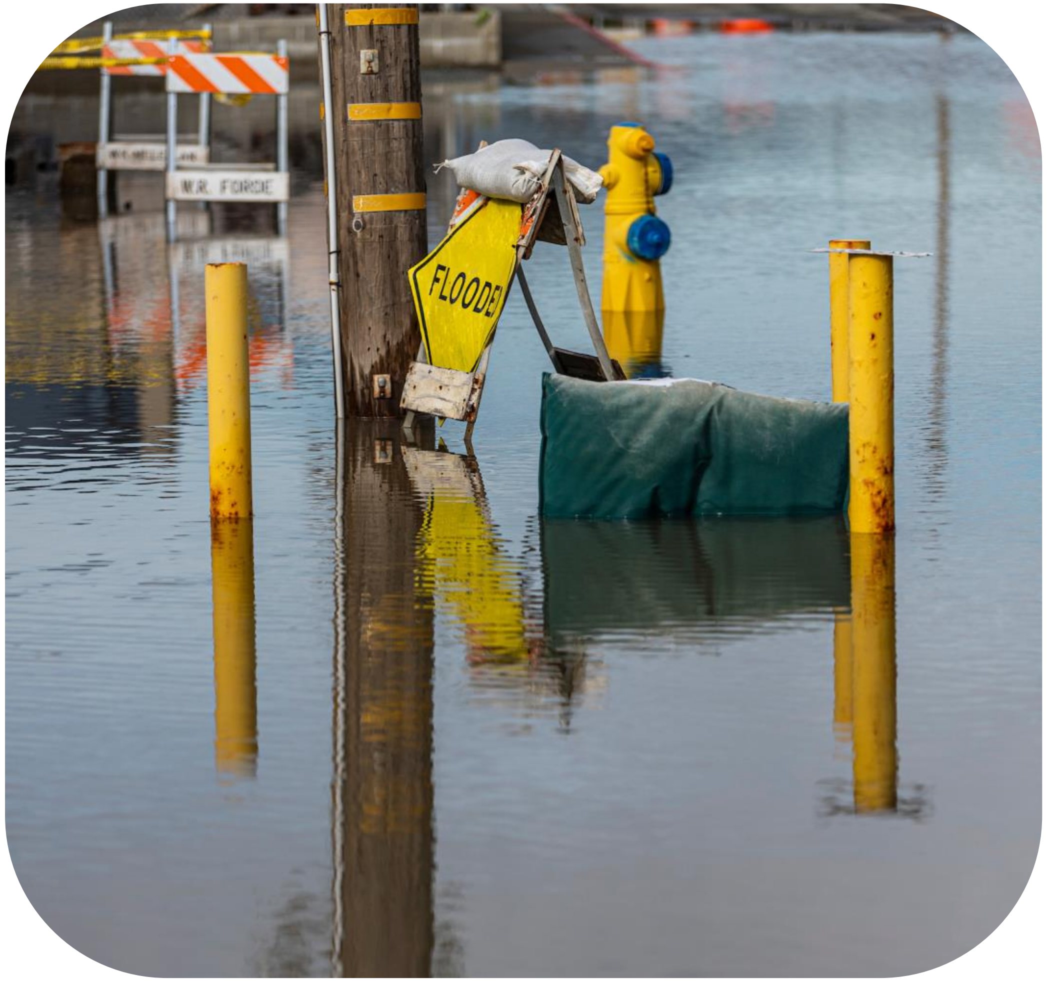


Image Credit: Andrew Innerarity, Hydrant in standing water on Gate 5 Road in Sausalito

PROJECT OBJECTIVES

Precipitation Analysis

Use GPM IMERG late run data to assess the feasibility of using satellite precipitation measurements in areas with sparse ground observations.

PROJECT OBJECTIVES

Precipitation Analysis

Soil Moisture Analysis

Review spatial trends of soil moisture to identify flood prone areas.

PROJECT OBJECTIVES

Precipitation Analysis

Soil Moisture Analysis

Flood Inundation Maps

Identify flooding extent in Salinas Watershed across the study period to identify locations within the valley that are susceptible to flooding.

PROJECT OBJECTIVES

Precipitation Analysis

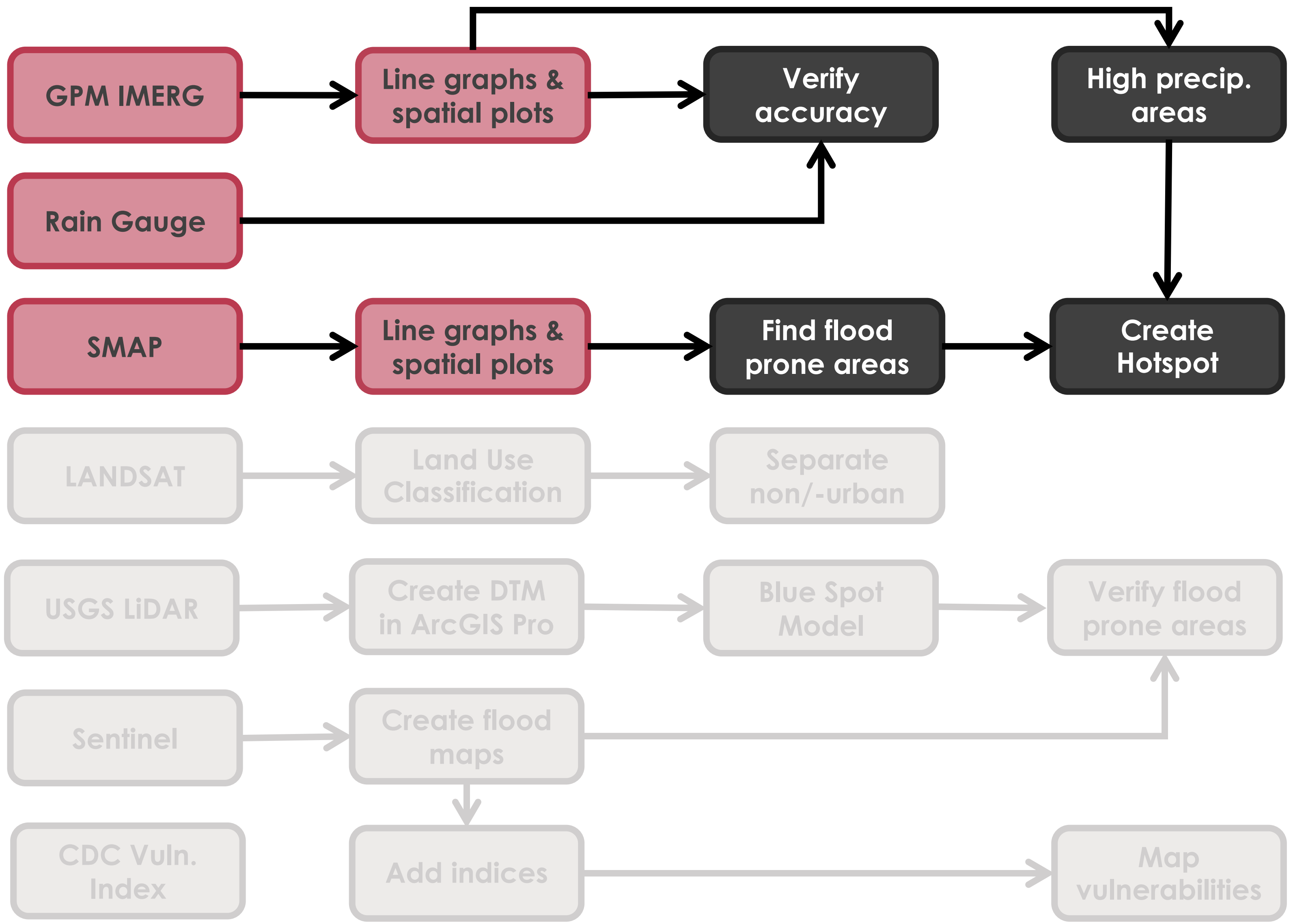
Soil Moisture Analysis

Flood Inundation Maps

Urban Flood Map Model

Input factors related to flooding and calculate risk at the neighborhood level

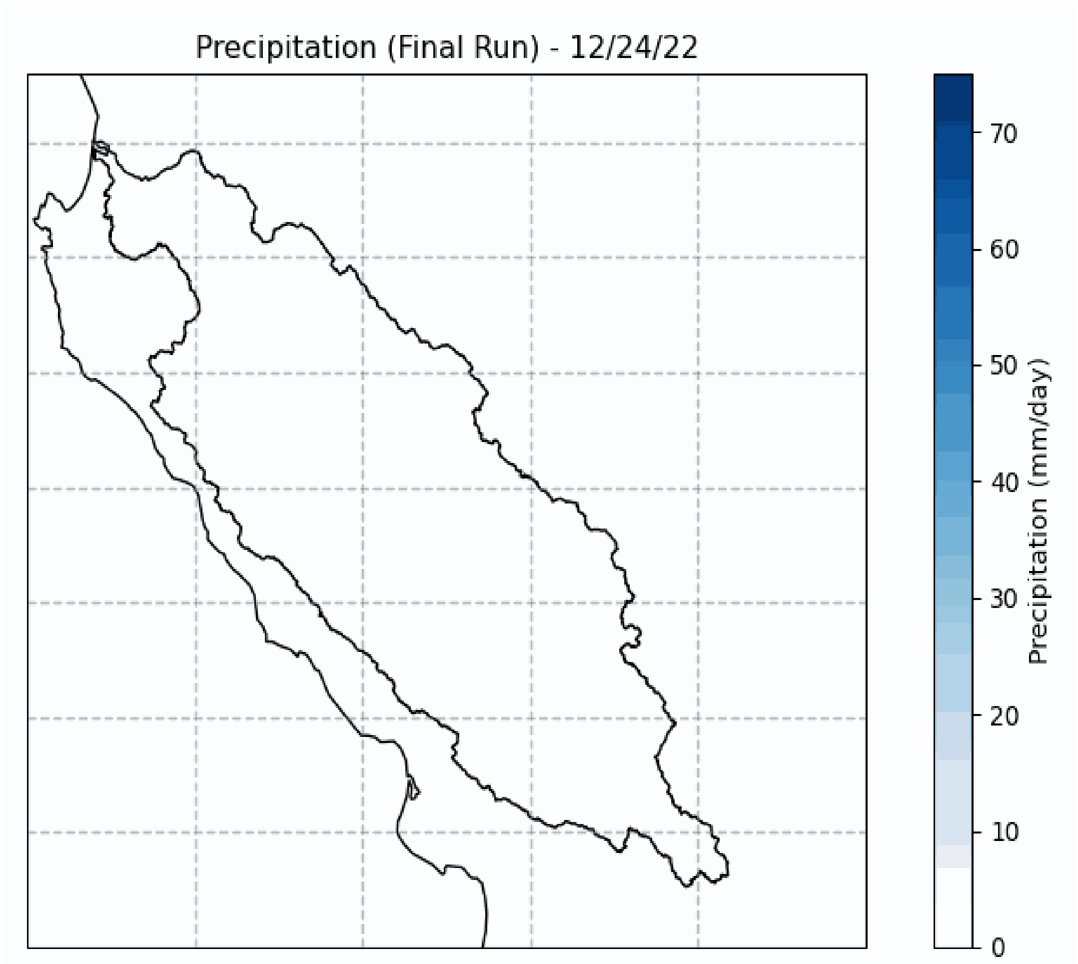
METHODOLOGY: Flood Contributors



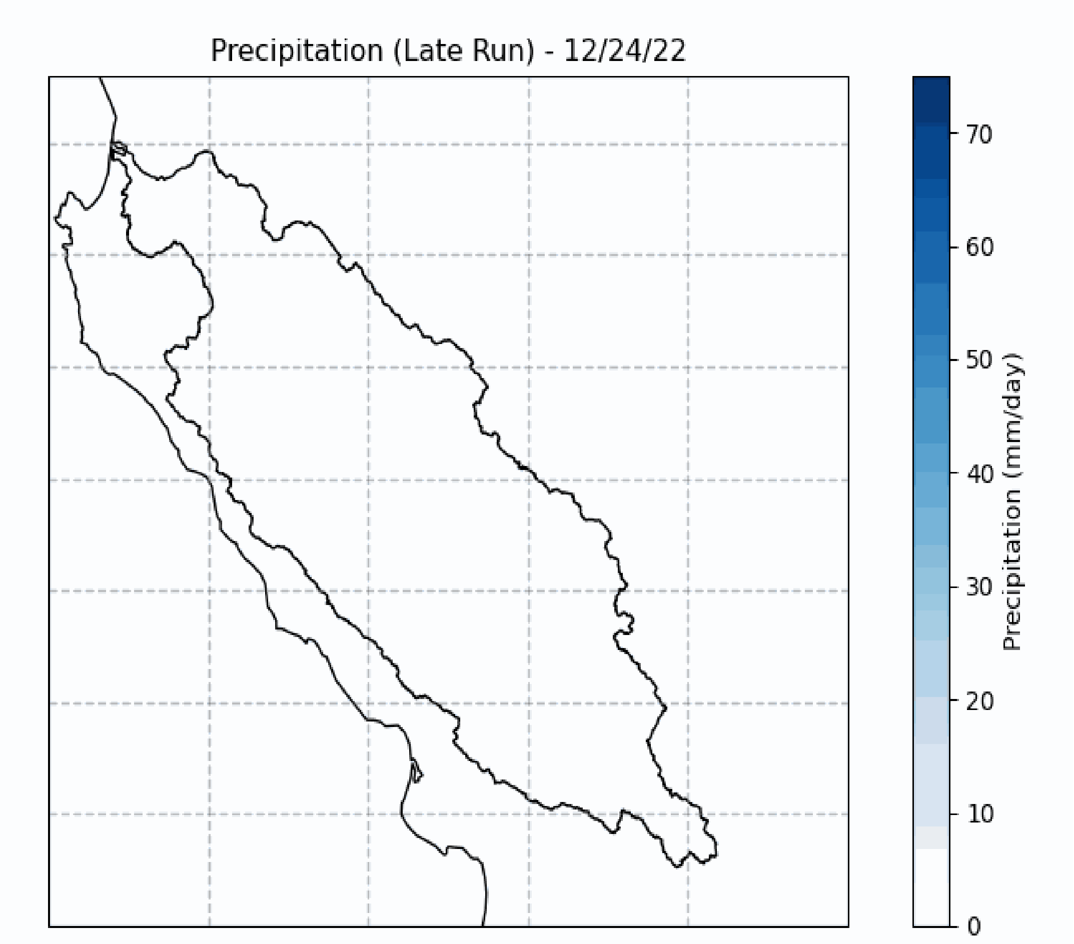
"Can NASA EOs help better assess **pluvial flooding** using GPM and SMAP data?"

GPM IMERG

GPM IMERG Final Run V07

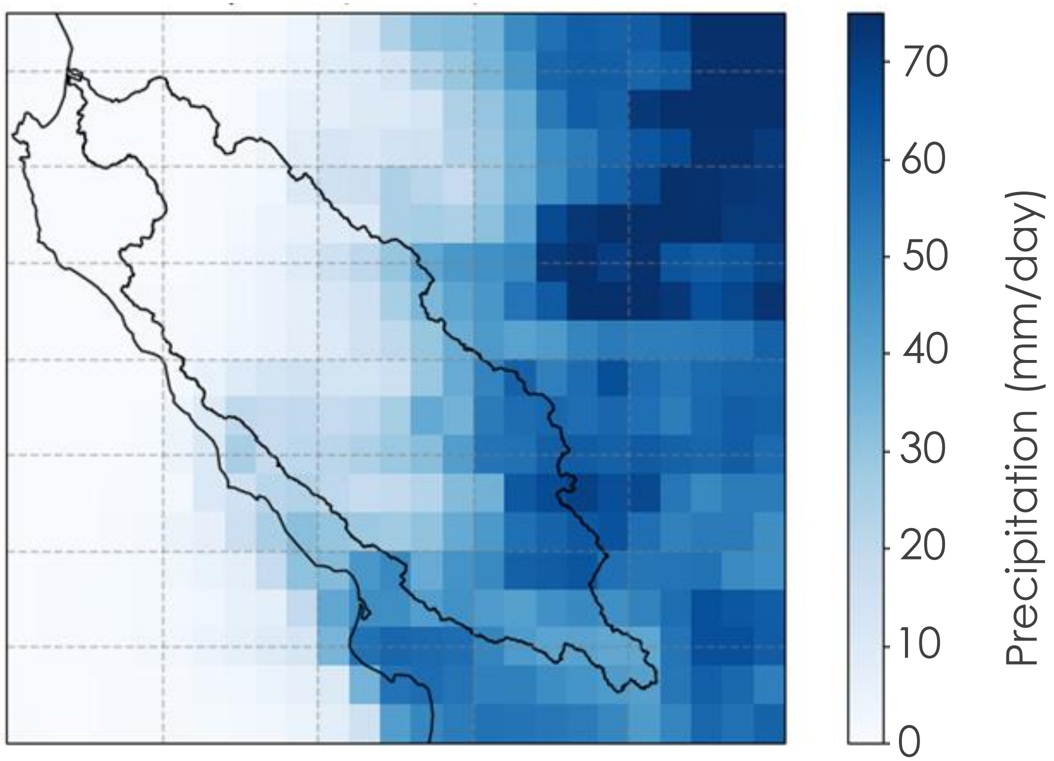


GPM IMERG Late Run V06

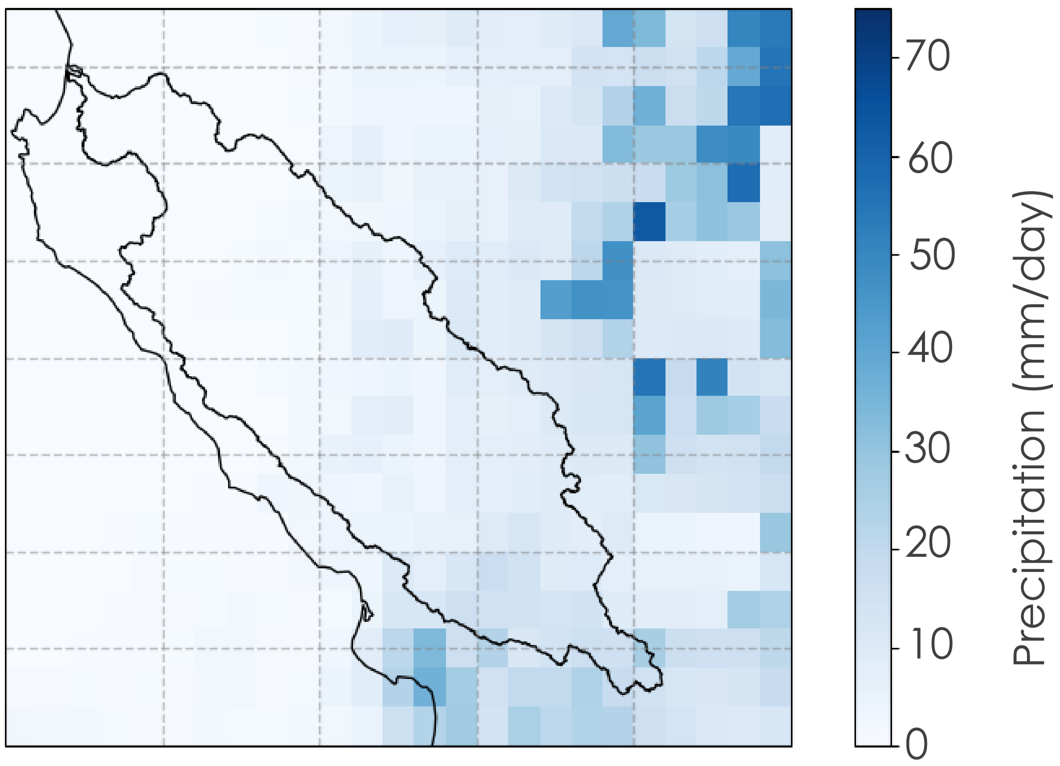


GPM Final Run v. Late Run

Precipitation measurement - Final Run

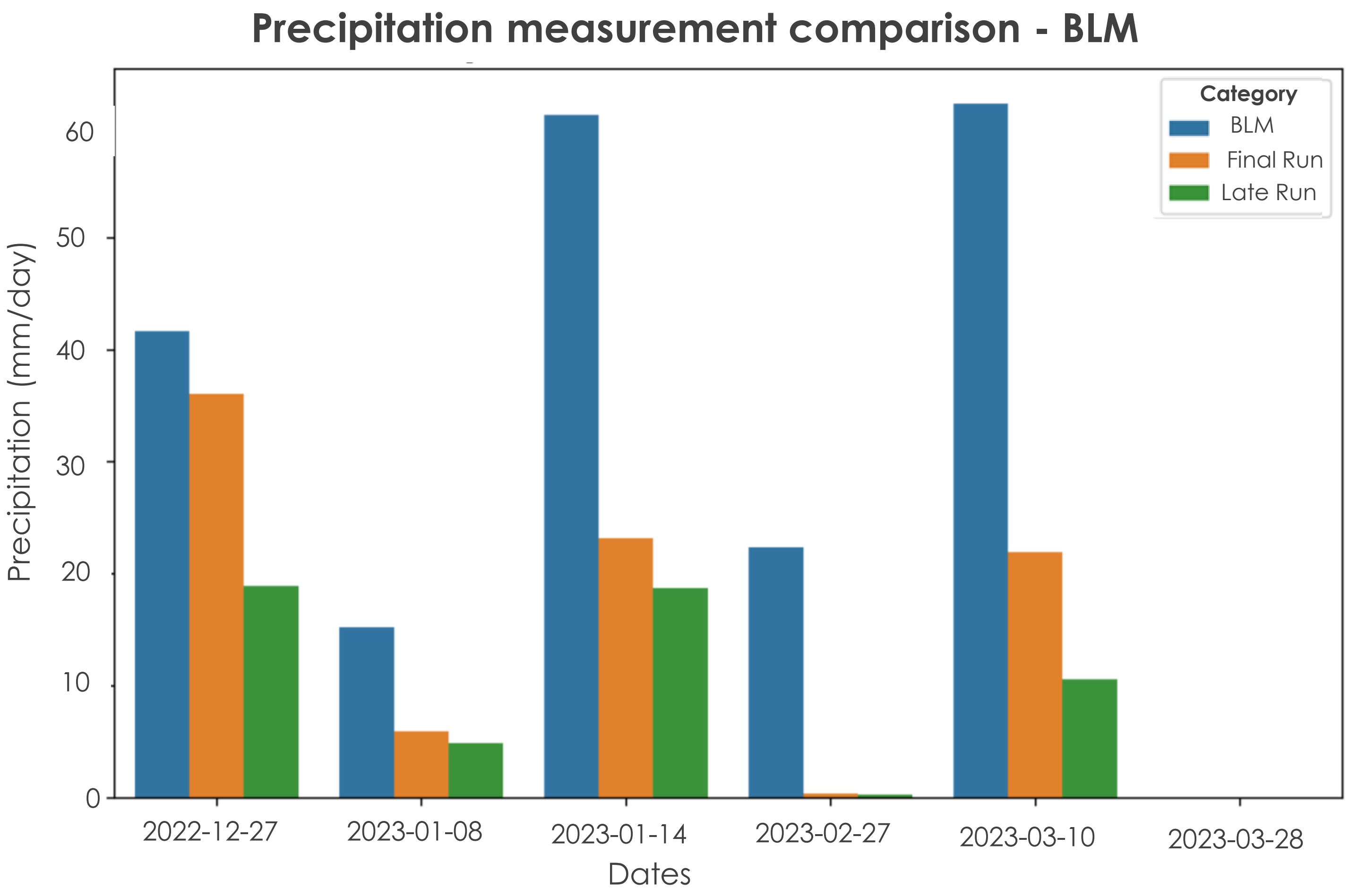


Precipitation measurement - Late Run



Both observations taken on 2/25/2023

GPM IMERG – Visual Comparison



Precipitation estimates from BLM rain gauge and closest identified GPM pixels at 35.35° N latitude and 120.34999 °W longitude

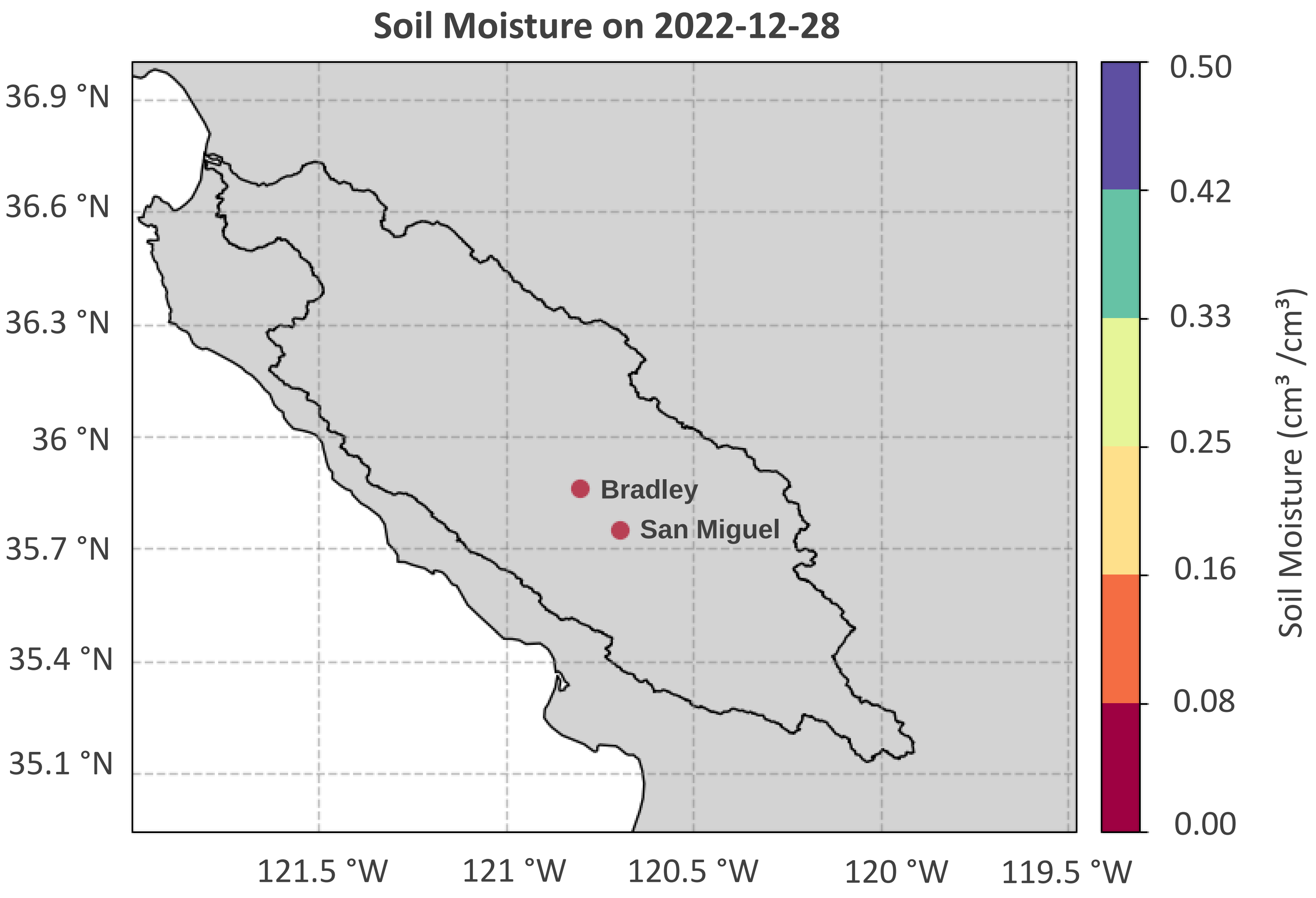
Insights

GPM IMERG Final Run **underestimated precipitation on an average of 33%** when compared with rain gauge data.

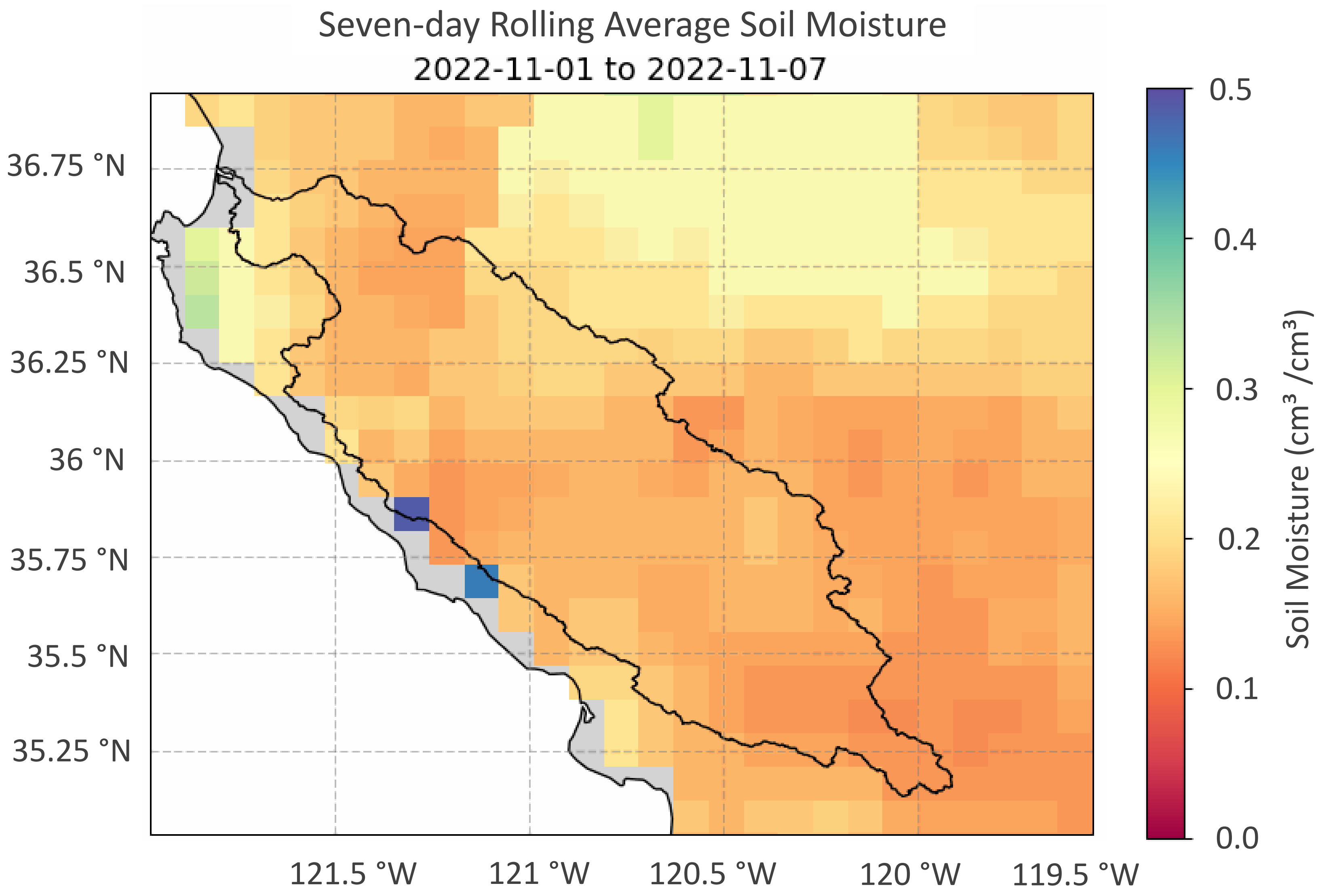
SMAP

Can we identify **flood-prone** areas with SMAP?

- 9km daily SMAP data
- A lot of data gaps – see example to the right
- Working with at least 3-day averages



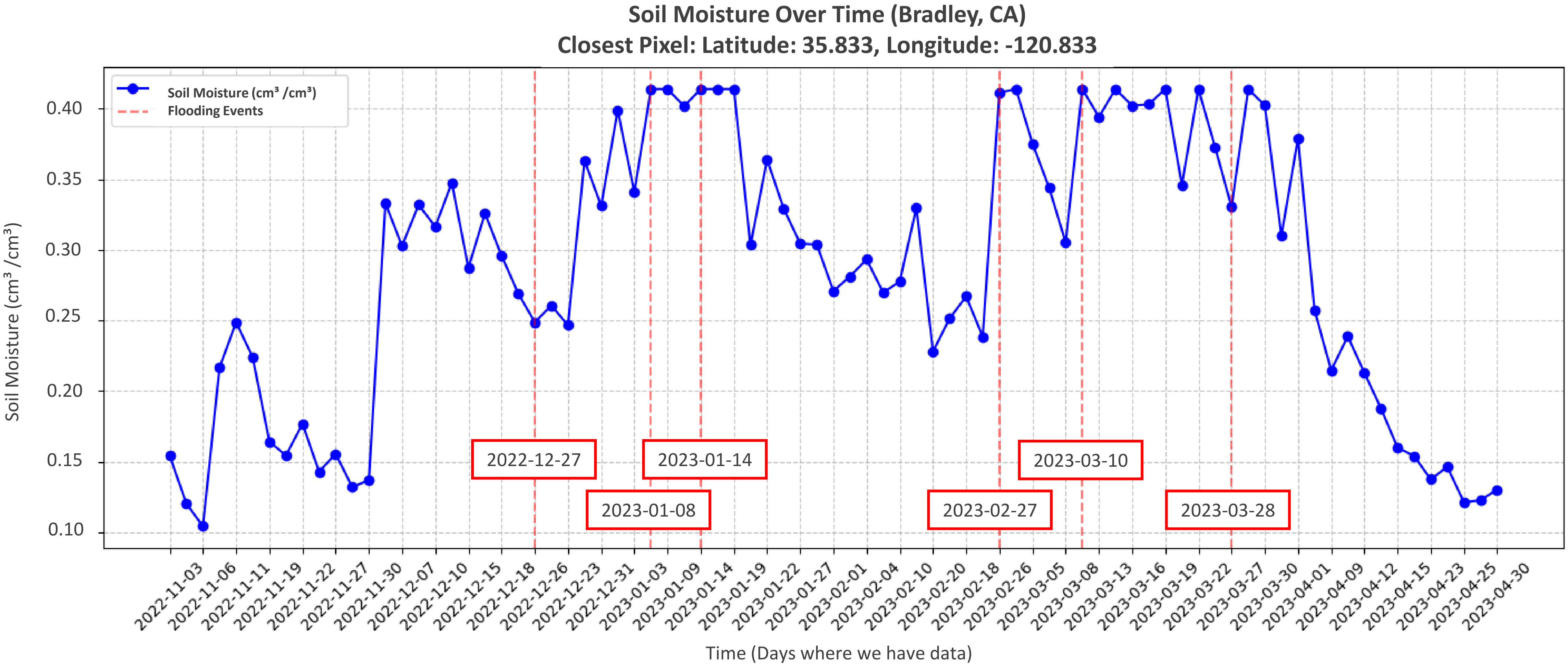
SMAP



Soil Moisture Summary

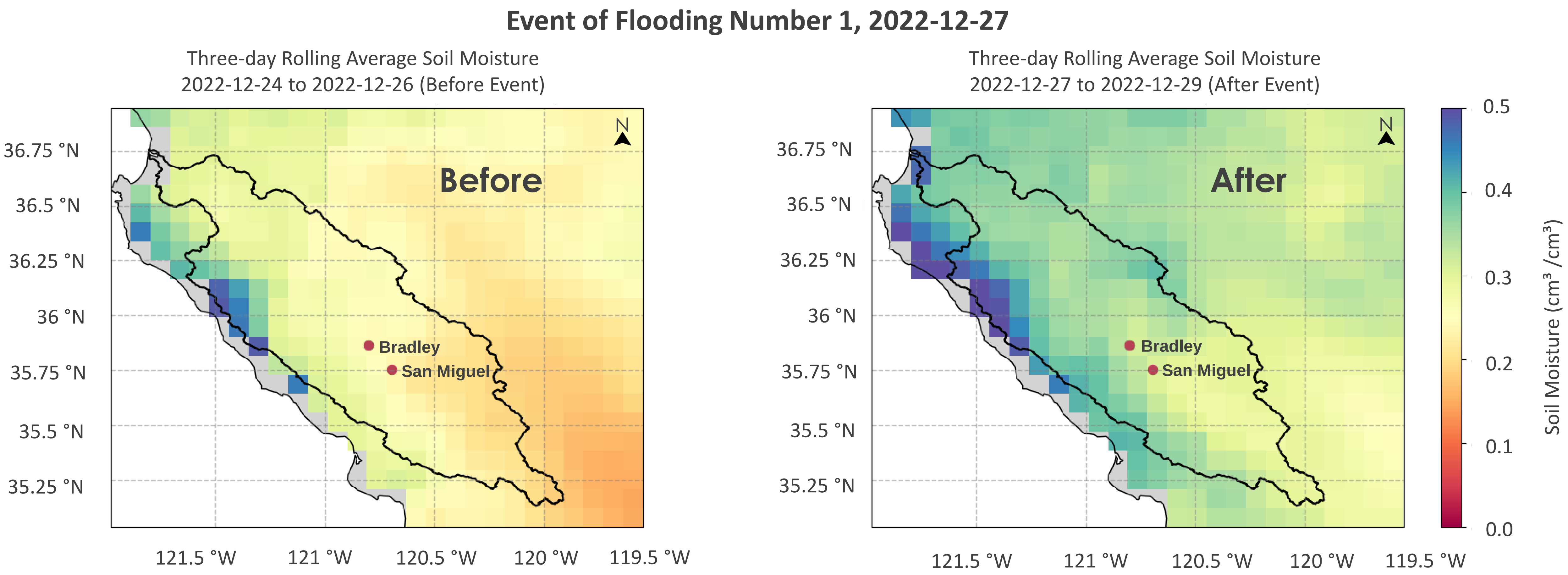
- Ratio of the volume of water present in the soil to the total volume of soil (**VWC**)
- Saturation means that soil pores are filled with water, and no more can be absorbed
- Around **50-60%**

SMAP



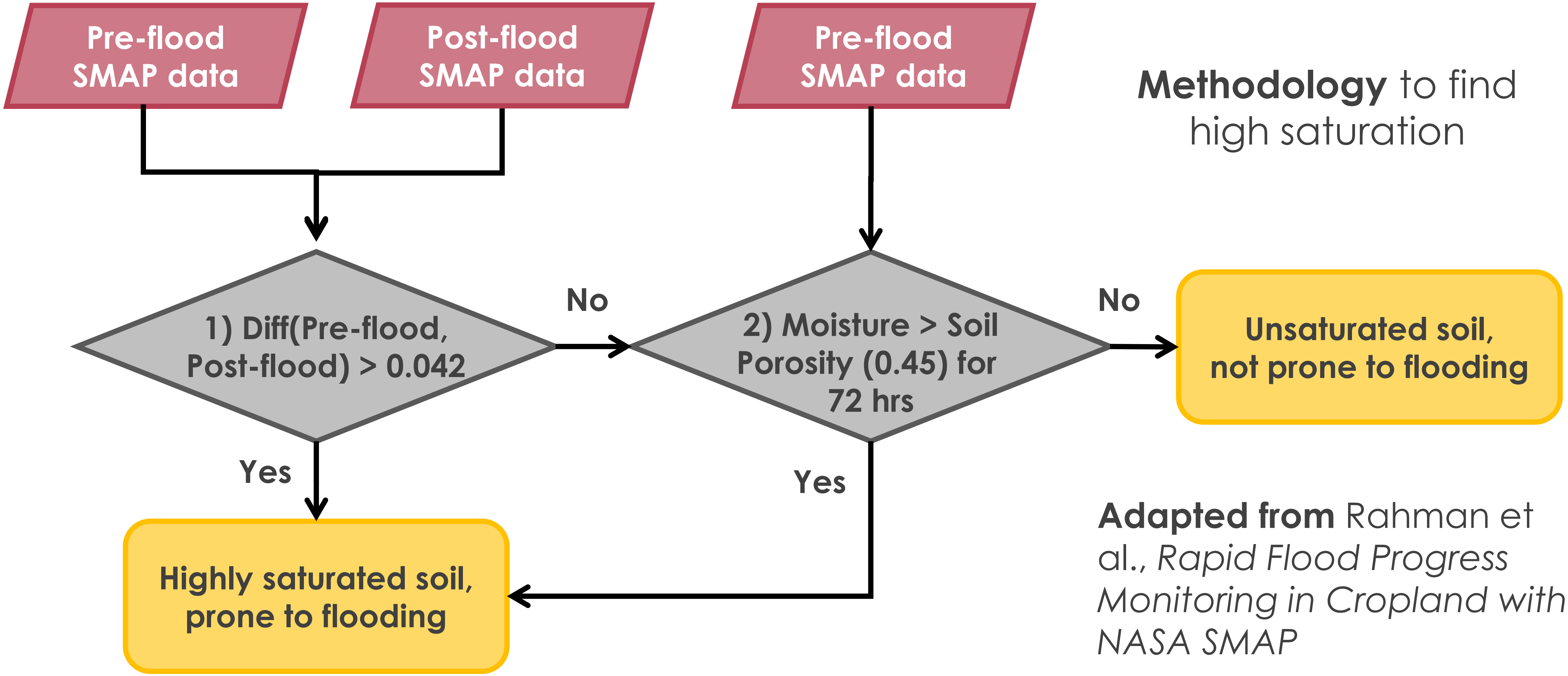
Actual flooding events are **represented** in the soil moisture line graph.

SMAP



How can we identify **flood-prone areas** based on the soil moisture?

SMAP

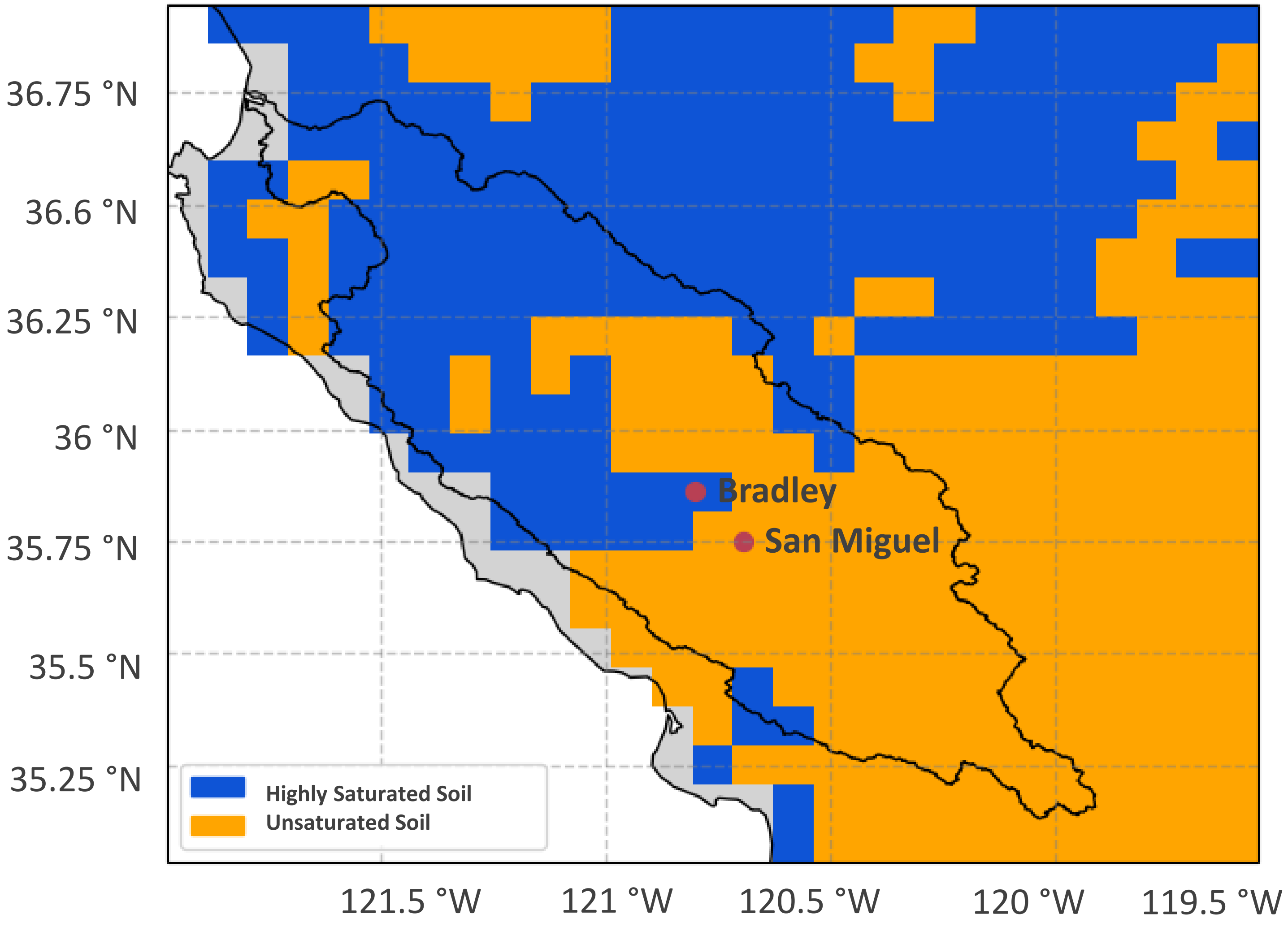


Methodology to find high saturation

Adapted from Rahman et al., *Rapid Flood Progress Monitoring in Cropland with NASA SMAP*

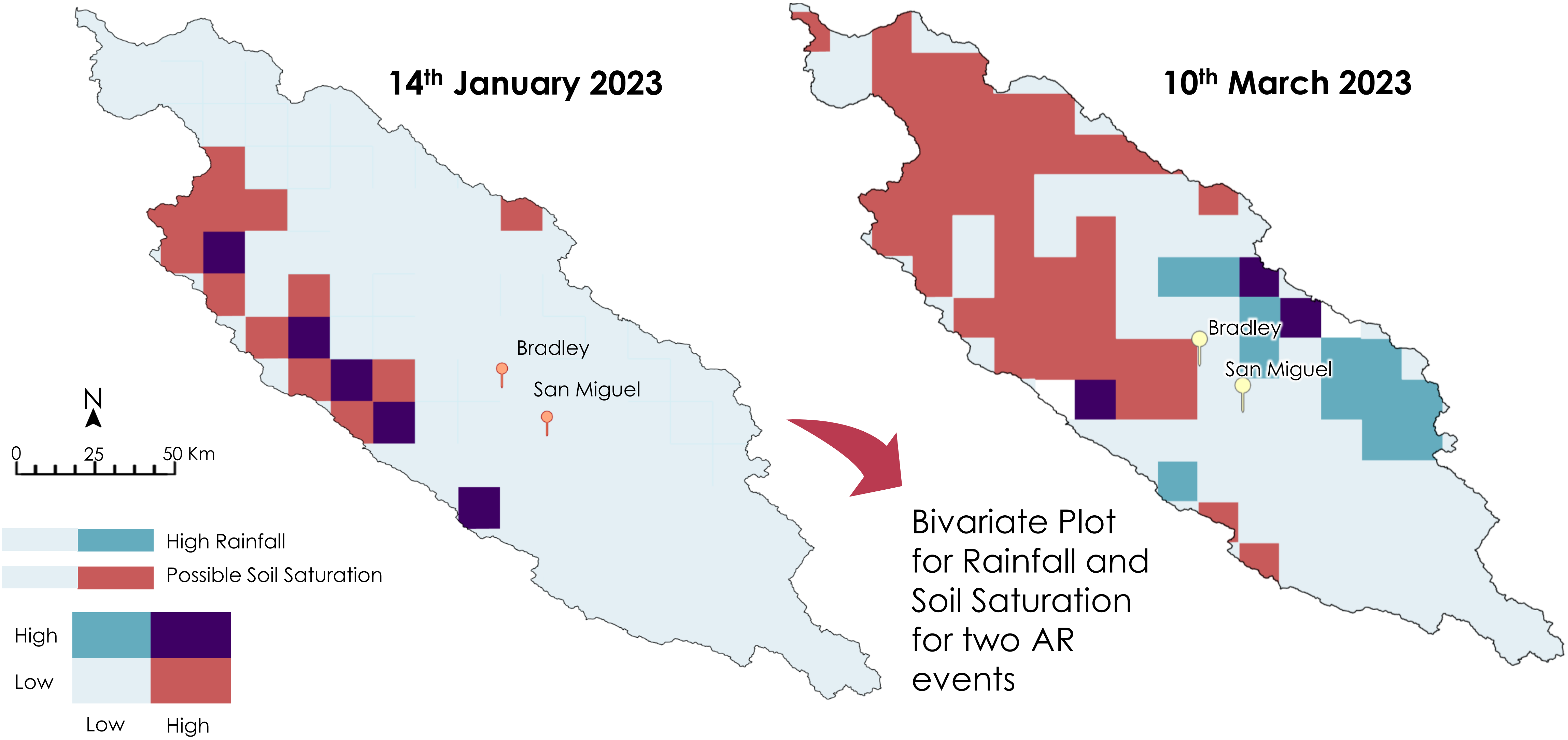
SMAP

Highly Saturated Soil, Event Number 5, 2023-03-10



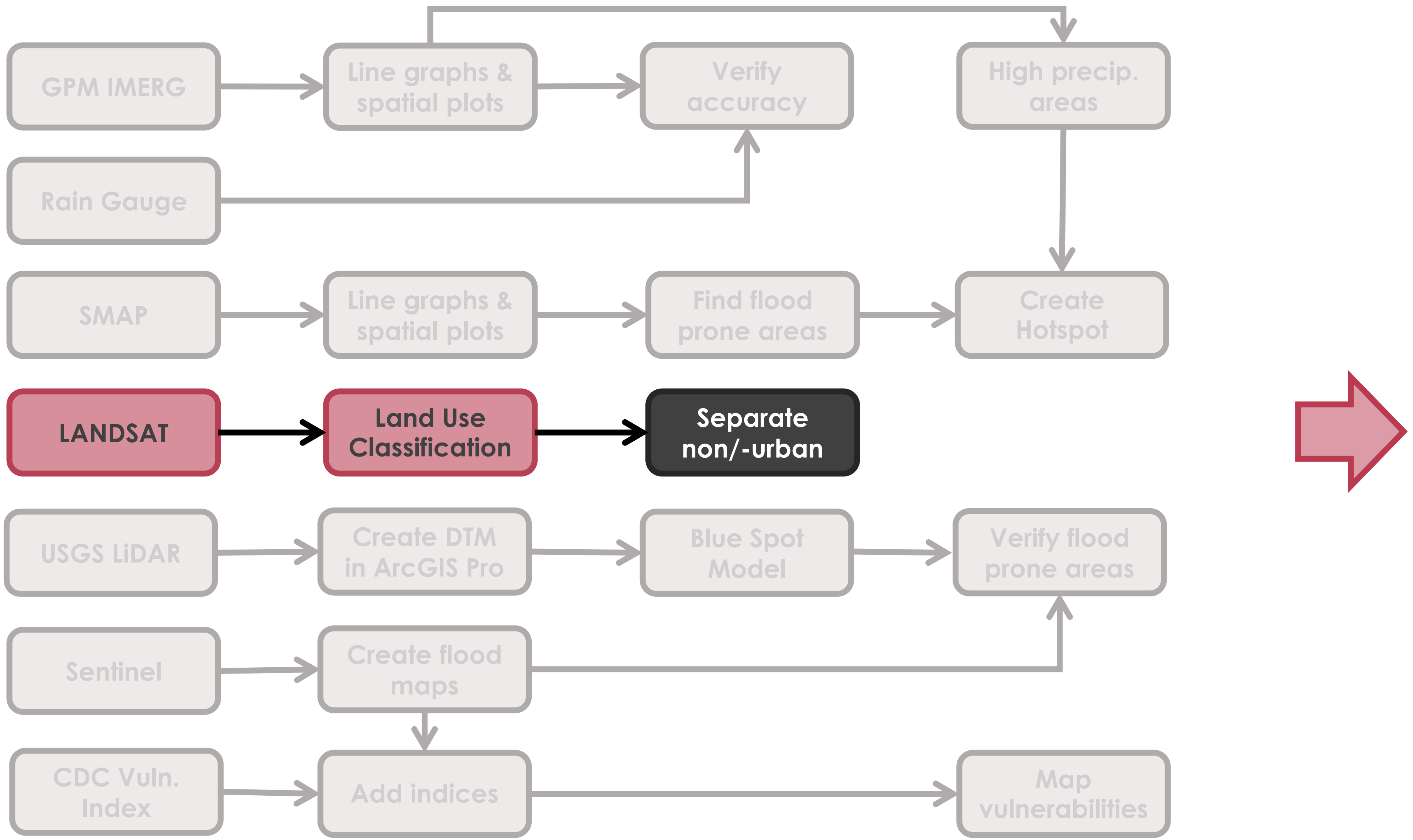
Export coordinates of identified data points and hand them over to create **the bivariate plot**

Rainfall and Soil Saturation



Bivariate Plot for Rainfall and Soil Saturation for two AR events

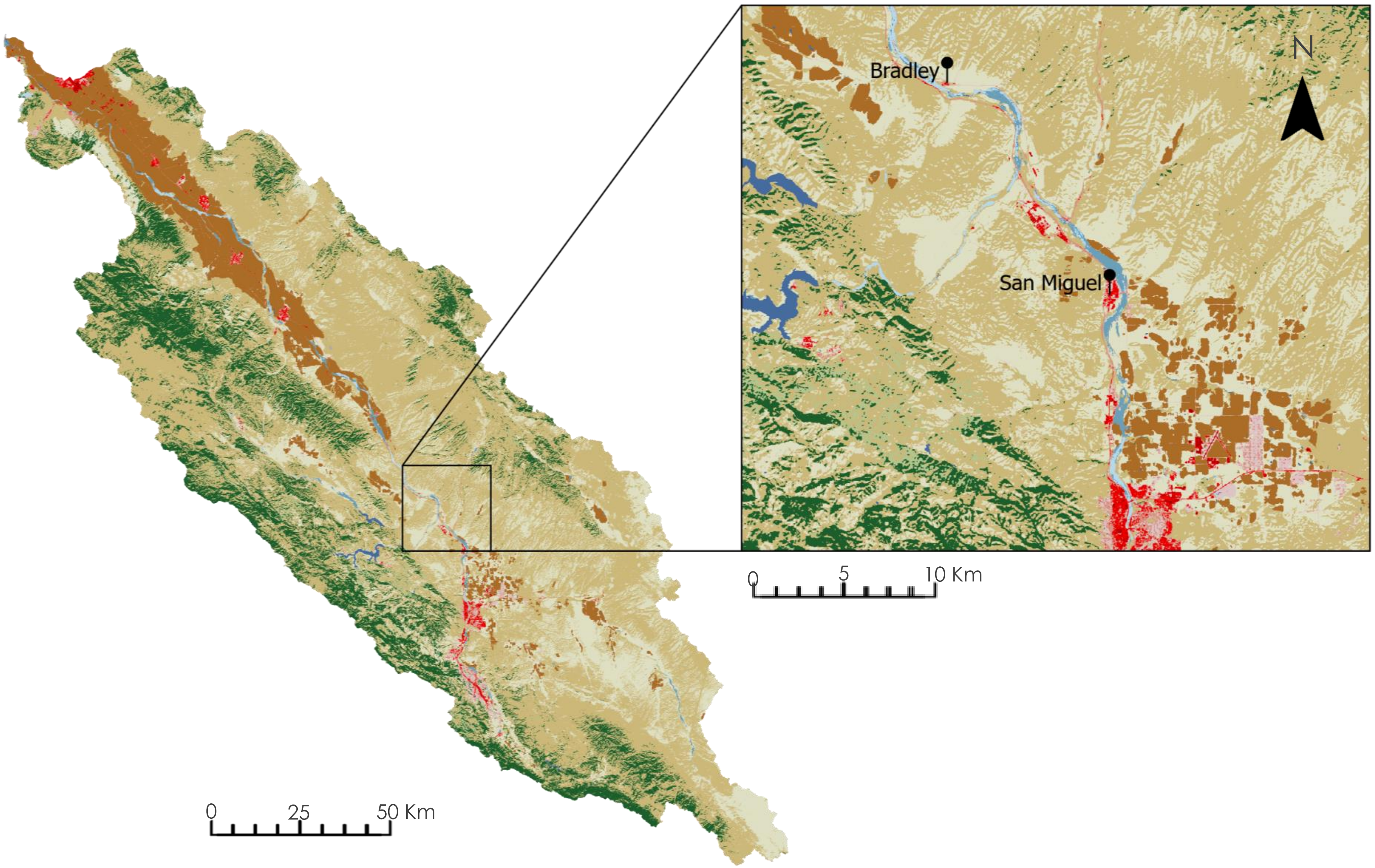
METHODOLOGY: Land Cover



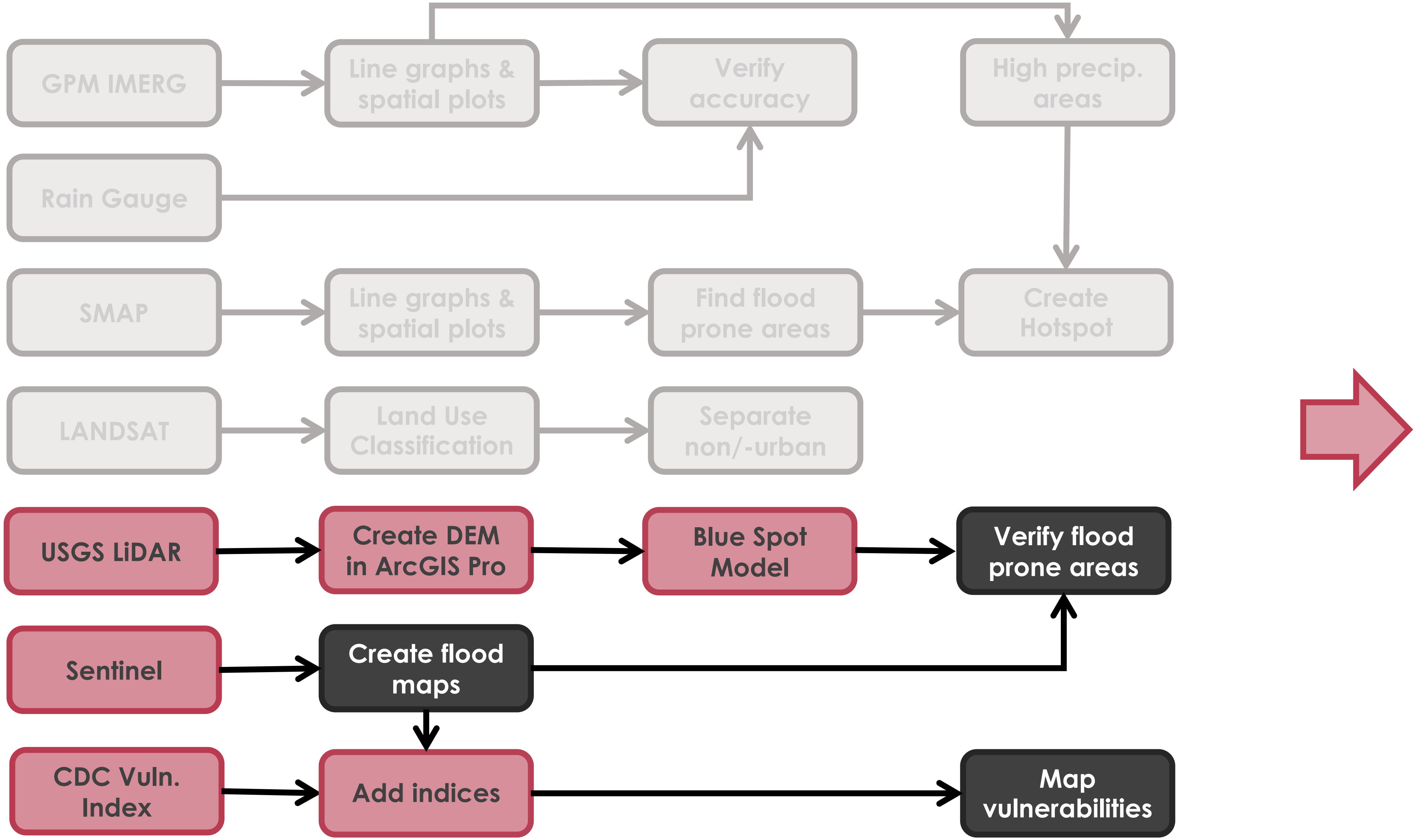
"Can NASA EOs help better assess **pluvial flooding** using GPM and SMAP data?"

LAND USE/LAND COVER

- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Herbaceuous
- Hay/Pasture
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceuous Wetlands

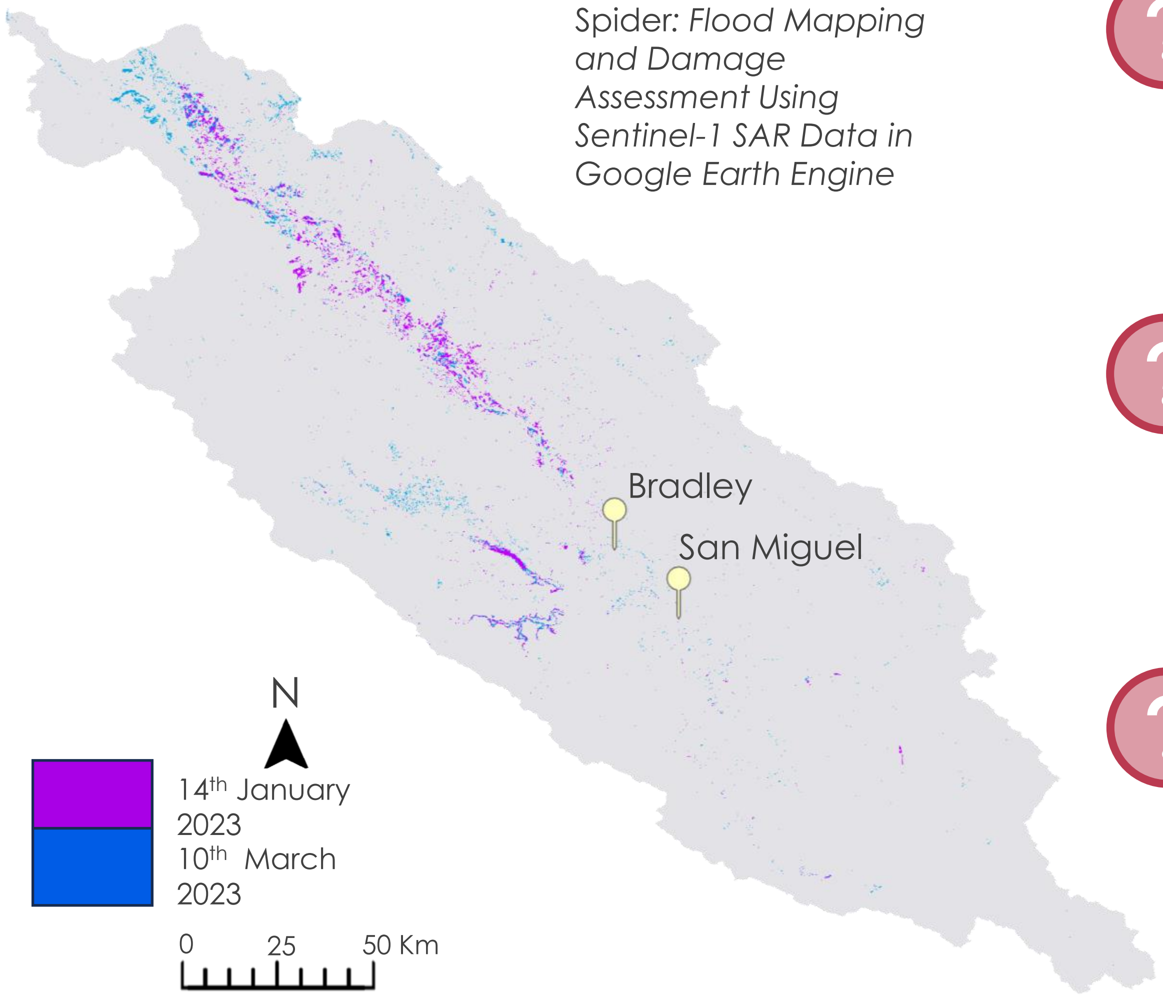


METHODOLOGY: Flood Risk



"Can NASA EOs help better assess **pluvial flooding** using GPM and SMAP data?"

Sentinel-1 – Possible Flood Inundations



Adapted from UN Spider: *Flood Mapping and Damage Assessment Using Sentinel-1 SAR Data in Google Earth Engine*

What is it?

- Synthetic Aperture Radar (SAR) imagery
- Not affected by cloud contamination
- Passes over every 6-12 days

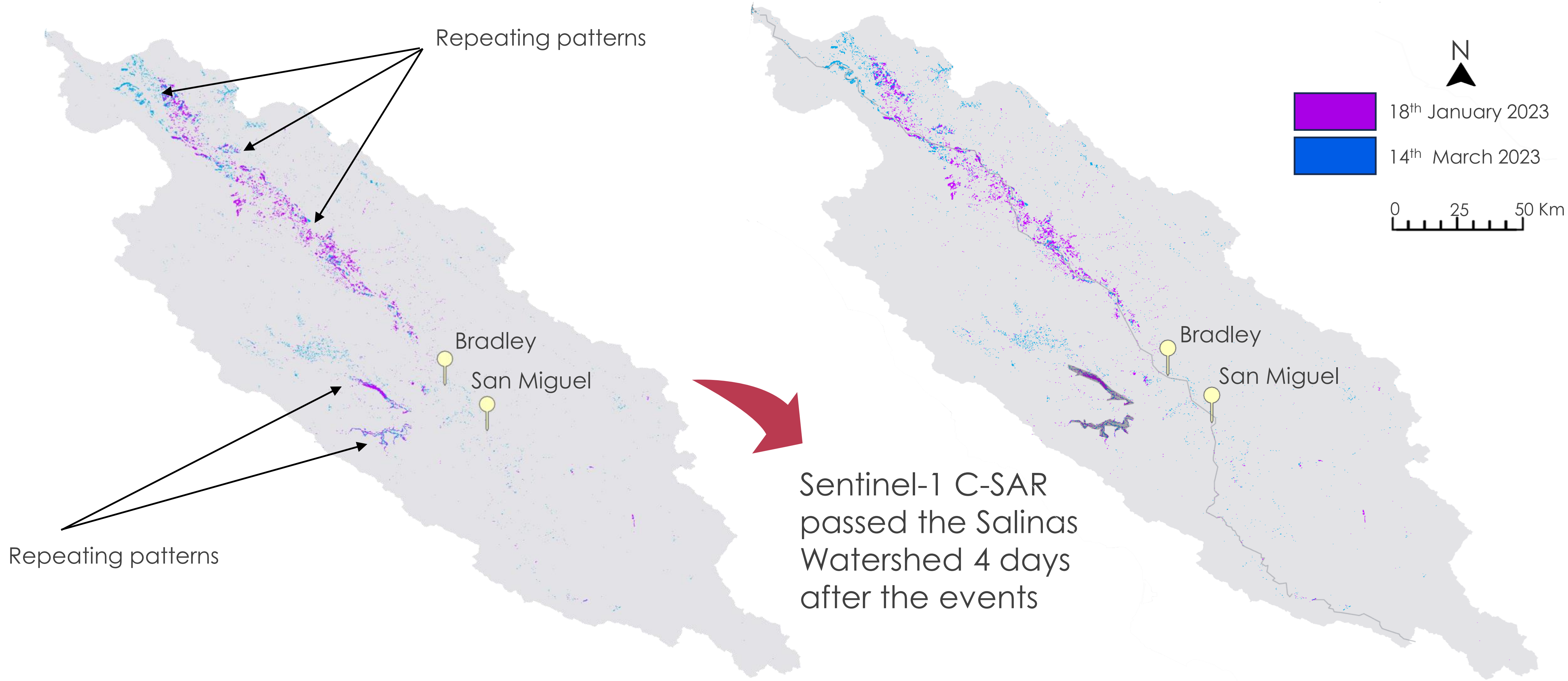
Why is it relevant?

- Can detect standing water
- In cases of pluvial flooding by ARs, there is near constant cloud cover

How did we do it?

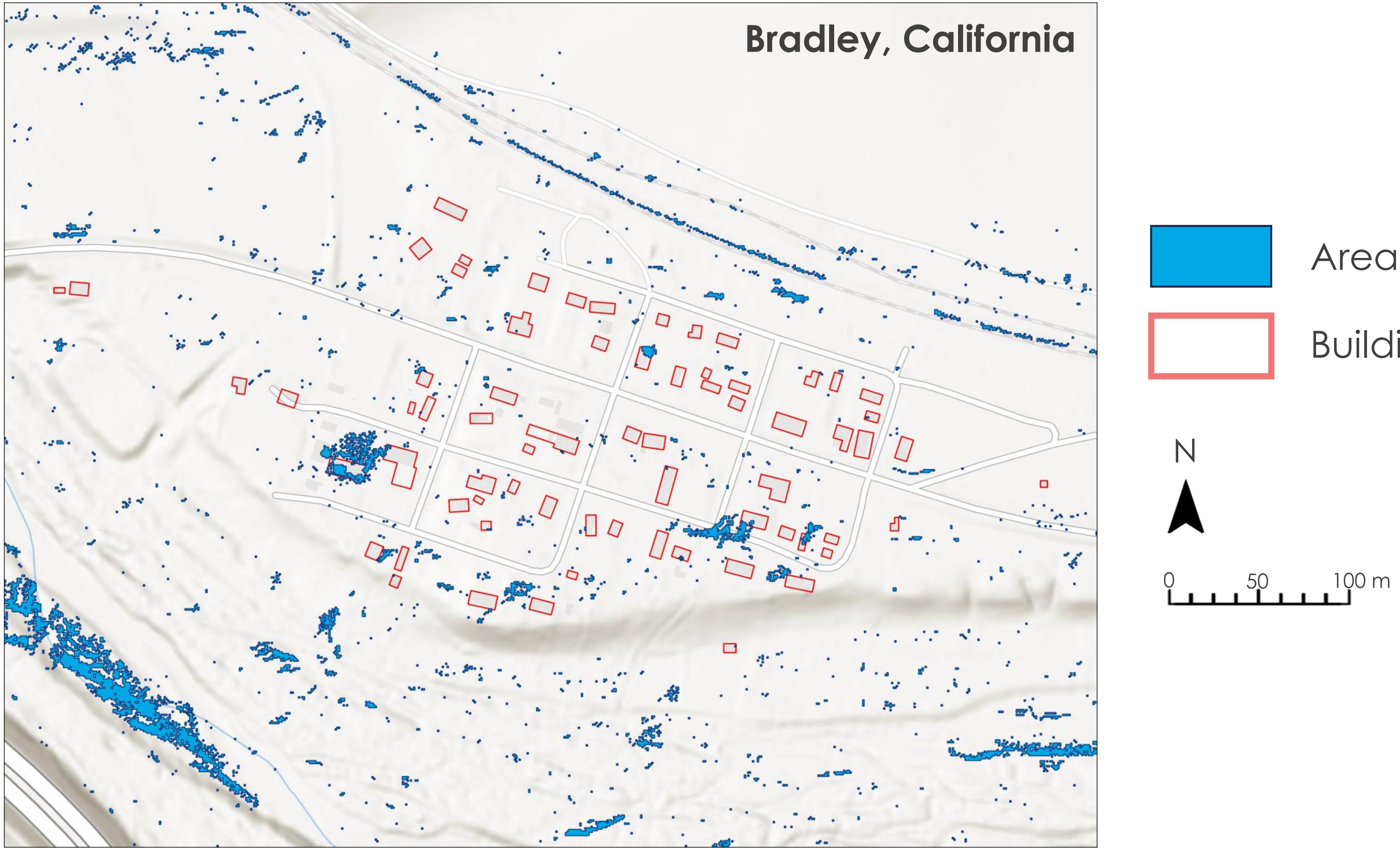
- Compared images from before and pass-over closest to AR events for 14th January and 10th March
- Set a threshold of -22 dB

Possible Flood Inundations



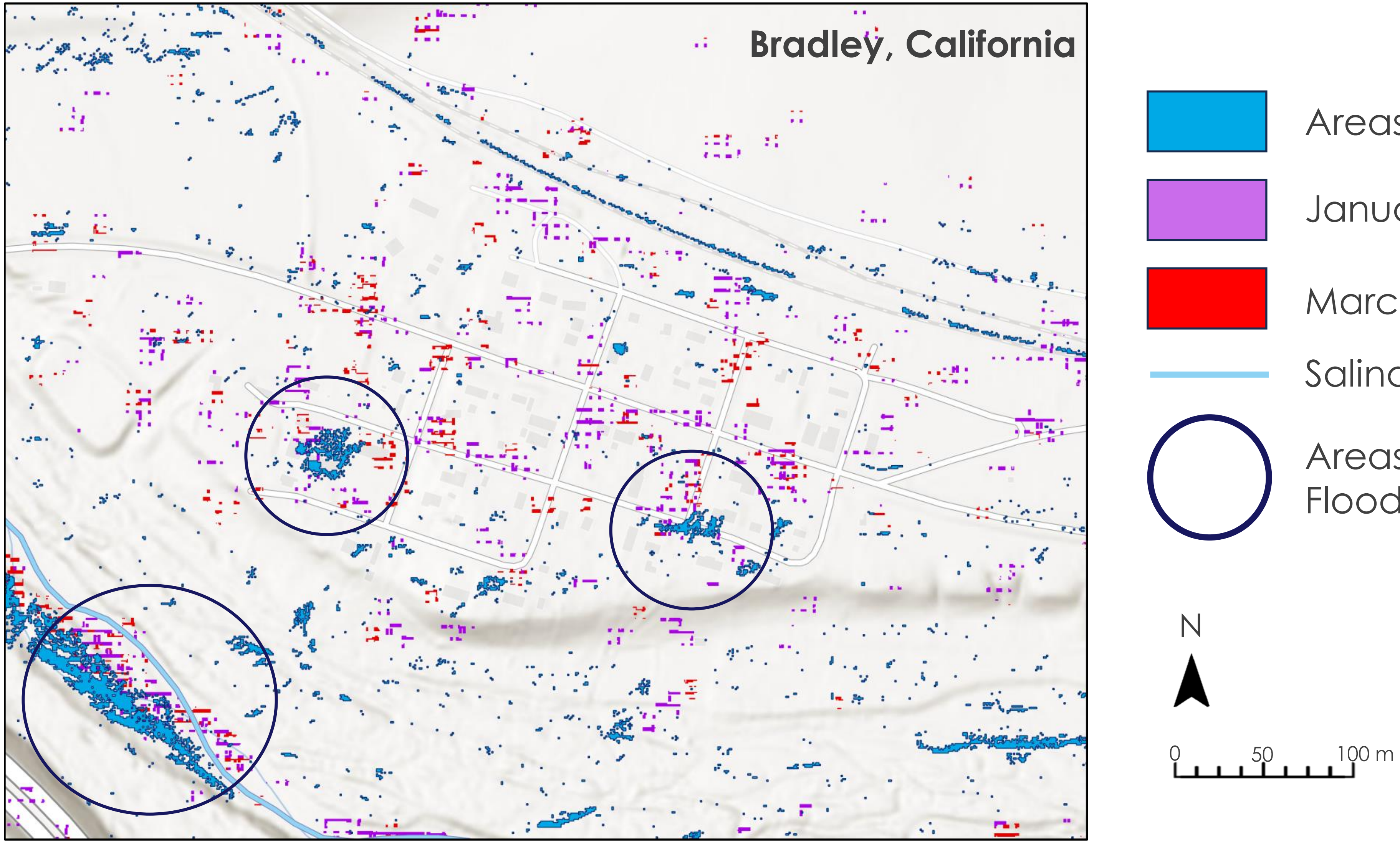
Sentinel-1 C-SAR passed the Salinas Watershed 4 days after the events

POTENTIAL FLOODING: Blue Spot Model



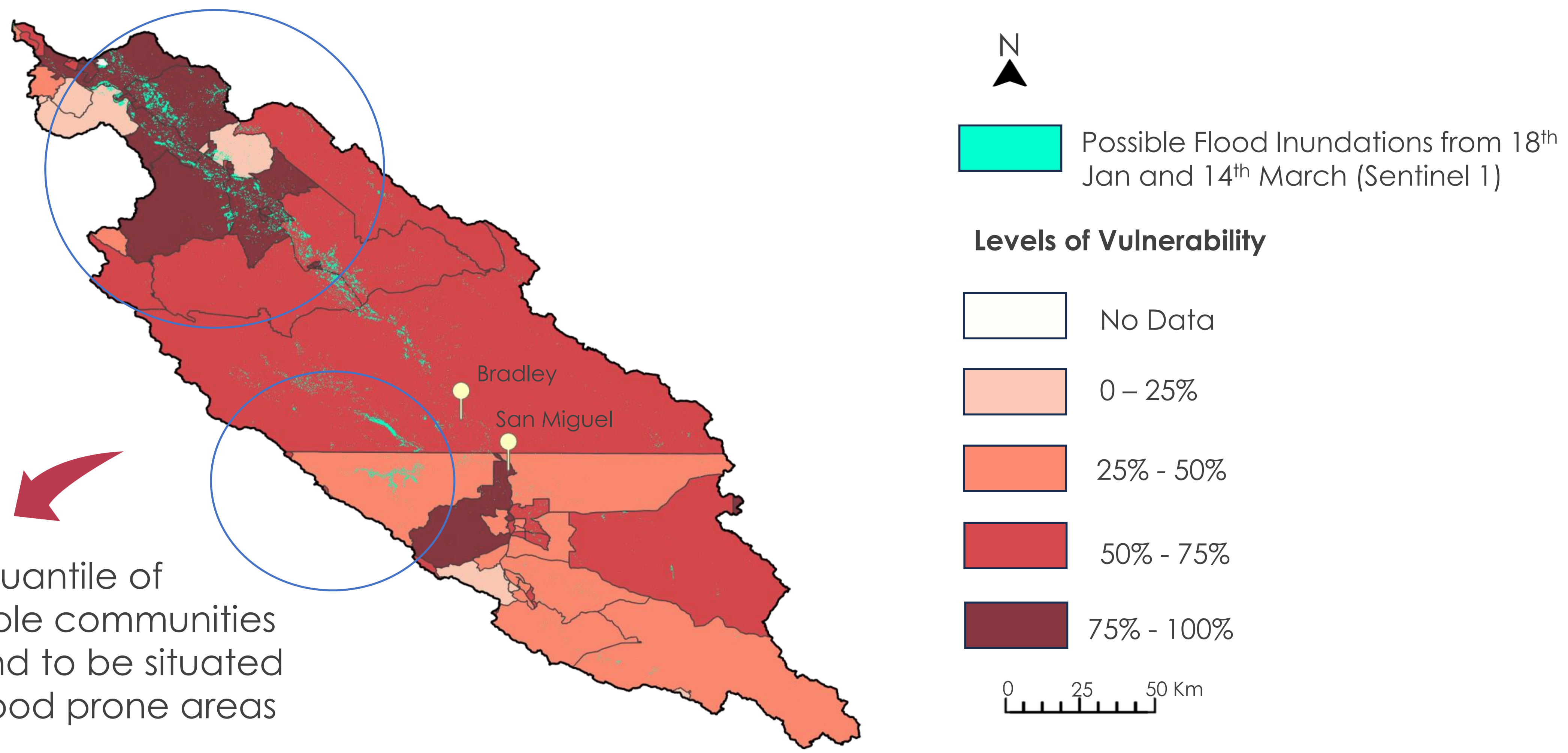
Basemap Credit: Esri Community Maps Contributors, California State Parks, © OpenStreetMap, Microsoft, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS

POTENTIAL FLOODING: Blue Spot Comparison



Basemap Credit: Esri Community Maps Contributors, California State Parks, © OpenStreetMap, Microsoft, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, USFWS

SOCIAL VULNERABILITY



Upper quantile of vulnerable communities are found to be situated in the flood prone areas

CONCLUSIONS

Flooding Contributors

GPM underestimates precipitation rates by an average of 33% as compared with in situ measurements due to beam-filling errors.

SMAP shows soil moisture played a role in the flooding of the 2022-2023 atmoshperic events.

Flood Risk

Sentinel 1 C-SAR imagery is good for detecting standing water and creating flood maps.

Blue Spot model is useful for identifying potential for pluvial flooding sites based on elevation.

Social Vulnerability

Study results suggest a positive relationship between flooding and **vulnerability**.

Topography and **land cover** play an important role in flood risk vulnerability.

"Can NASA EOs help better **assess** pluvial **flooding** using GPM and SMAP data?"

FUTURE RECOMMENDATIONS

Flooding Contributors

- Use a model to track changes in water budget between atmospheric river events
- Use imagery of a finer resolution for soil moisture plots

Flooding Flood Risk

- Explore the feasibility of using of Near Real Time imagery
- Consider geospatial record-keeping for past floods

Image Credit: Ken James, floodwaters inundating River Road

Acknowledgments

DEVELOP Lead

- Isabel Lubitz, Maryland – Goddard

California Department of Water Resources

- Dr. MD Haque
- Dr. Michael Anderson
- Weihua (Wayne) Li

Science Advisor

- Dr. Venkataraman Lakshmi, University of Virginia

Others

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- Dr. Xia Cai, NASA Langley Research Center
- Marisa Smedsrud, DEVELOP Project Coordination Fellow
- Benjamin Goffin, University of Virginia
- Dr. Bin Fang, University of Virginia

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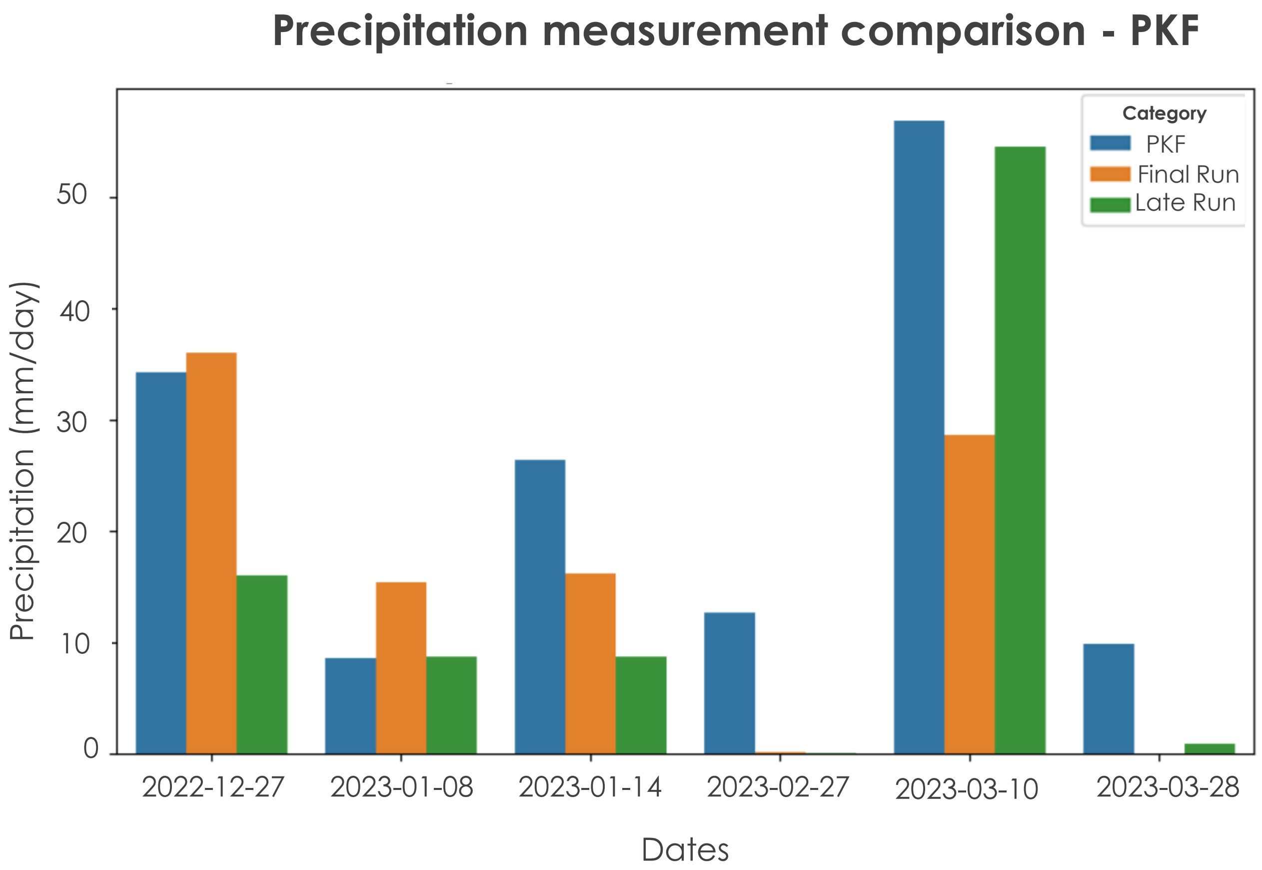
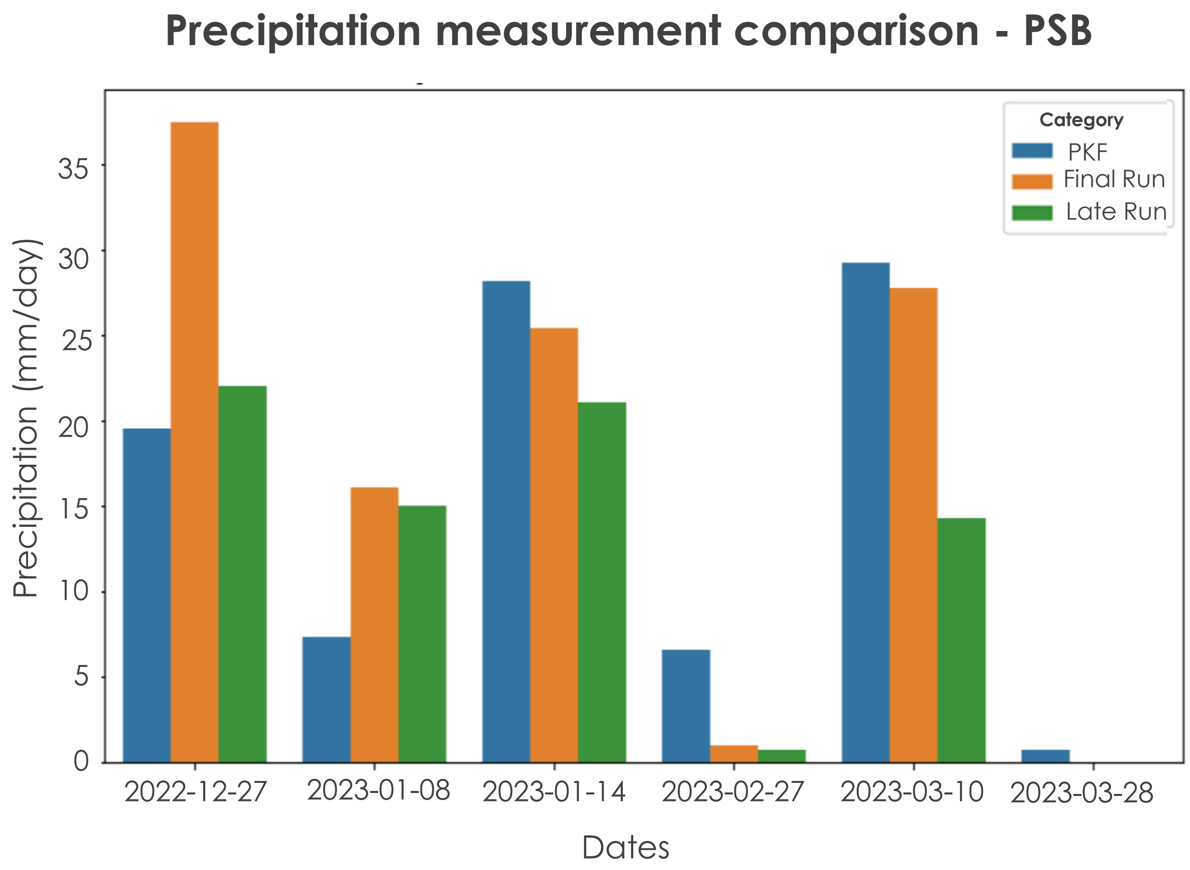
GPM IMERG – Statistical Analysis

Statistical analysis to measure accuracy and performance of satellite data

Sl No.	Rain Gauge	Satellite Product	CC	Relative Bias (%)	ME (mm)	RMSE (mm)	POD	FAR
1	ARY	Final Run V07	0.843	-48	9.9	17.6	0.931	0.069
		Late Run V06	0.872	-52.5	9.7	18.4	0.965	0.152
2	PKF	Final Run V07	0.834	-8.5	4.5	8.7	0.857	0.2
		Late Run V06	0.813	-44.2	5.3	9.8	0.929	0.212
3	PSB	Final Run V07	0.915	-5.9	2.7	5.1	0.913	0.25
		Late Run V06	0.822	-29.3	3.7	7.1	0.869	0.31
4	PAS	Final Run V07	0.834	-20.6	5.5	10.4	0.852	0.179
		Late Run V06	0.741	-46.9	6.3	13.2	0.889	0.172
5	BLM	Final Run V07	0.789	-54.4	14	31.5	0.833	0.2
		Late Run V06	0.851	-72	15.5	34.8	0.917	0.29
6	SMB	Final Run V07	0.751	-60.9	19.6	40.1	0.957	0.214
		Late Run V06	0.728	-69.2	20.2	42.8	0.957	0.29

GPM IMERG – Visual Comparison





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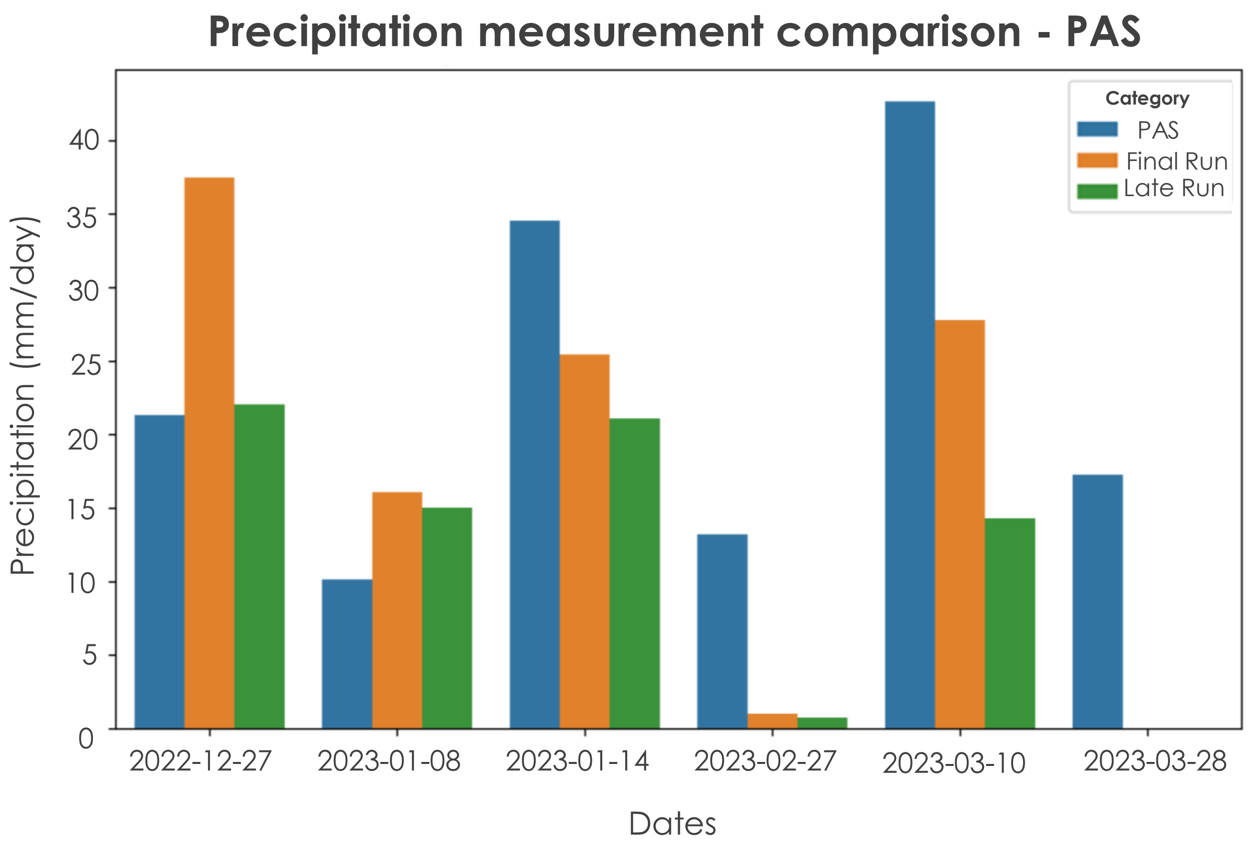

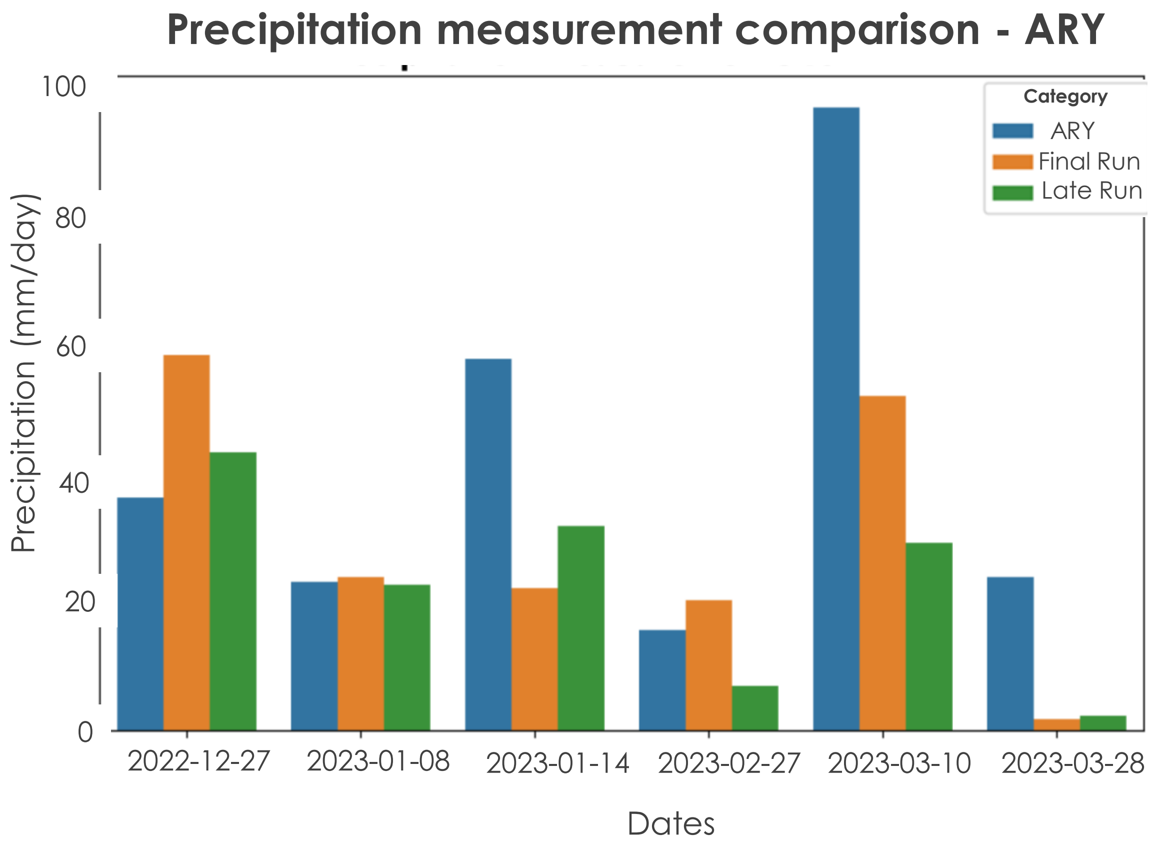

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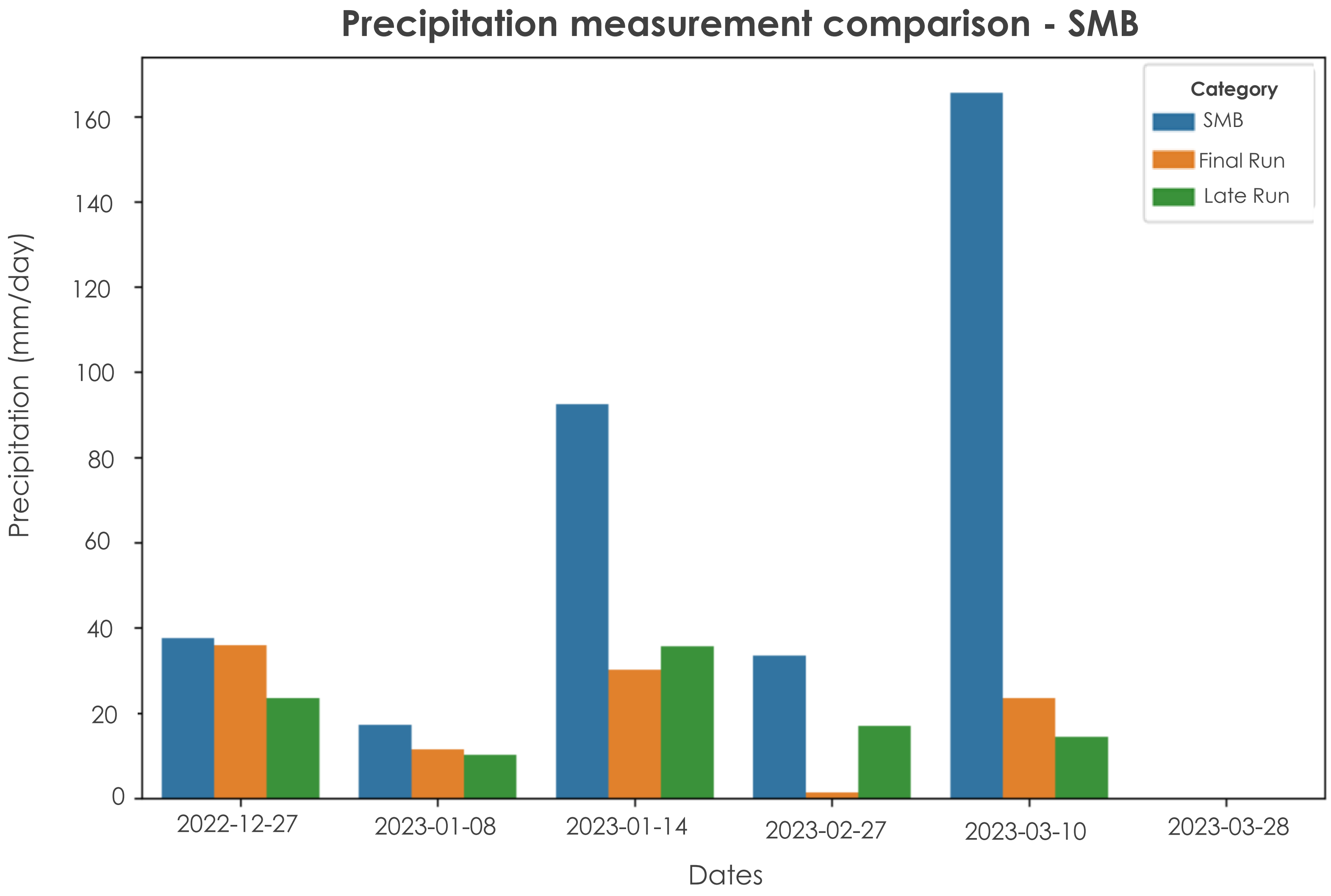
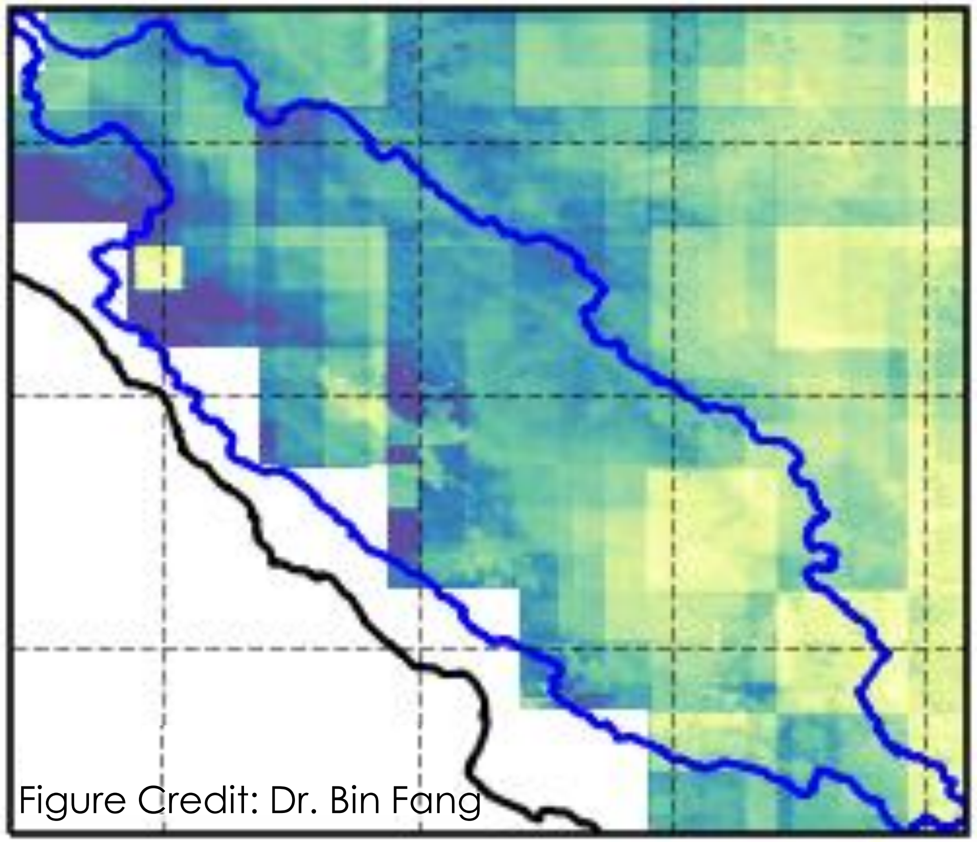


SMAP

SMAP Spatial Resolution: 1km, 2023-01-19



SMAP Spatial Resolution: 9km, 2023-01-19