# Rainfall-Soil Moisture Event Responses near Baton Rouge, Louisiana

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## Introduction

Rainfall controls soil moisture variability and drives hydrological processes from infiltration to contaminant transport. This study investigates event-scale rainfall-soil moisture interactions near Baton Rouge, Louisiana, during 2022-2024. We detect and analyze individual rainfall events, quantify associated soil moisture responses, and assess seasonal patterns in their magnitude and variability. The focus is on the change in soil moisture ($\Delta\theta$) as an indicator of infiltration dynamics.

Our results provide insight into how antecedent wetness and event precipitation shape soil moisture responses across seasons. Beyond immediate hydrological interpretation, this framework offers a basis for future extensions, including nitrate leaching and surface-subsurface contamination analysis, once nutrient datasets are integrated.

## Study Area and Data

The analysis domain is a 25 × 25 km box surrounding Baton Rouge, Louisiana (SW: 30.34000, -91.28000; NE: 30.56000, -91.02000), as shown in Fig. 1. This bounding box was chosen to capture regional hydroclimatic variability while maintaining a tractable spatial scale for event-based soil moisture analysis. Both precipitation and soil moisture datasets were subsetted spatially to this domain and temporally to the period 2022–2024.


**Figure 1:** Study area near Baton Rouge, Louisiana. The analysis domain (25 × 25 km box) is outlined and overlain on regional context.

Soil moisture conditions were obtained from the NASA Soil Moisture Active Passive (SMAP) mission, using the Enhanced Level-3 Radiometer Global Daily product (9 km resolution), which provides surface soil moisture retrievals representative of the top ∼5 cm of soil [1]. Precipitation data were obtained from the Global Precipitation Measurement (GPM) mission's Integrated Multi-satellite Retrievals (IMERG) Final Run product, available at 0.1° spatial and daily temporal resolution [2].

Together, SMAP and IMERG provide harmonized, global-scale, open-access satellite observations suitable for characterizing - moisture interactions in regions such as Baton Rouge, where high-frequency precipitation events and strong seasonal cycles affect vadose-zone hydrology.

## Methods

Rainfall events were defined from daily precipitation $P_t$. A wet day is $P_t \geq 1$ mm, and an event is a sequence of wet days that (i) starts after a dry day, and (ii) includes a burst of at least 5 mm on the first or second day. For an event with start $s$ and end $e$, total rainfall and duration are

$$R = \sum_{t=s}^{e} P_t, \qquad D = e - s + 1.$$

Antecedent soil moisture is the mean of the three days before the event, but if these overlap with the previous event, we trim them. Let $A$ denote this window and $\theta_A$ its average. The post-event response window is

$$B = \left[s,\ \min(e+3,\ s_{\text{next}} - 1)\right], \qquad \theta_{\max} = \max_{t \in B} \theta_t.$$

The main metric is the soil moisture increment

$$\Delta\theta = \theta_{\max} - \theta_A.$$

We also compute a nominal lag between antecedent and response times. However, we do not analyze it further because SMAP provides only surface soil moisture (∼0–5 cm) at daily resolution. With no information from deeper layers, infiltration timing and true lags cannot be extracted reliably. If multi-depth soil measurements were available, lag analysis would be a valuable extension.

## Results

**Hydroclimatic context.** Monthly precipitation and domain-mean soil moisture (Fig. 2) track each other closely, with wetter months yielding higher soil moisture. Peaks occur at the end of winter and early spring, reflecting cumulative cool-season rainfall and low evaporative demand.

**Rainfall events.** Event characteristics are shown in Fig. 3. The median event produced 25 mm over 2 days. High-depth, long-duration outliers (above the 75th percentile in both) occurred mainly in summer. Seasonal counts were Winter 31, Spring 31, Summer 29, and Autumn 23.

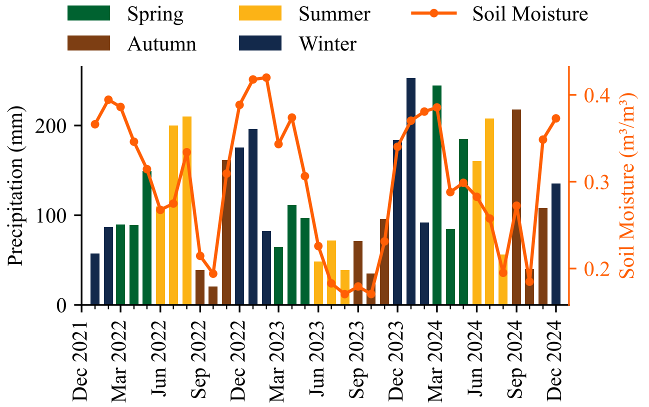


**Figure 2:** Monthly precipitation totals and averaged soil moisture from 2022–2024.

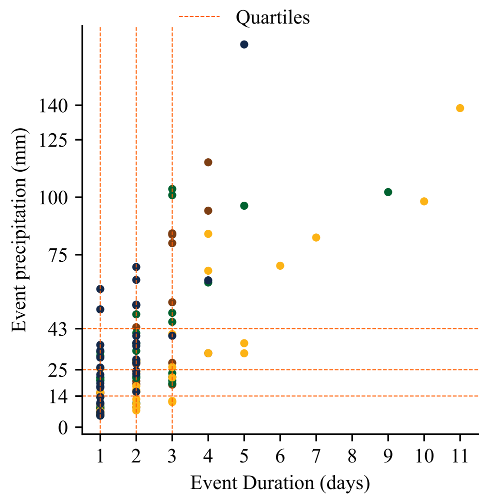


**Figure 3:** Event rainfall depth versus duration.

**Soil moisture responses.** For each event, the soil moisture increment ($\Delta\theta$) was calculated. Fig. 4 illustrates sample events; smaller storms were sometimes missed by detection rules. Across all events (Fig. 5, top), $\Delta\theta$ had a median of 6% and a maximum near 18%. The left panel shows a clear saturation boundary: high antecedent moisture limits responses, while drier soils allow larger increases. Winter and spring cluster near saturation, consistent with Fig. 2, whereas summer–autumn span drier antecedent states with responses from 0–18%. The right panel relates $\Delta\theta$ to precipitation: most events (0–50 mm) produced variable responses, indicating rainfall depth alone does not constrain soil moisture change.

## Future Research

Future research could potentially extend this event-based framework by coupling - moisture responses with a fully integrated water–heat–nitrate modeling approach, similar to recent work by Fahs and colleagues [3]. Such coupling would allow assessment of how storm-driven infiltration dynamics influence not only moisture but also temperature effects and nitrate mobilization in the vadose zone, thereby linking observed $\Delta\theta$ signatures to broader water-quality implications under seasonal variability.

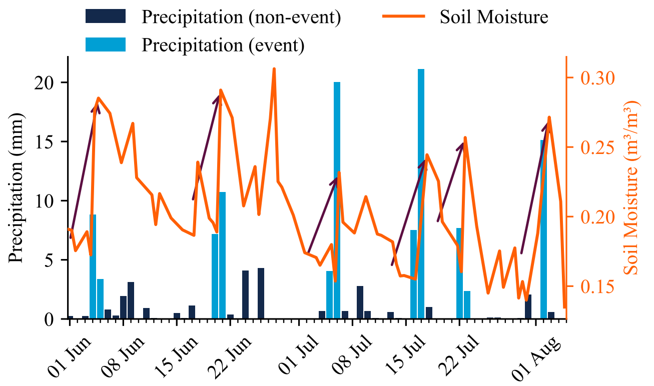


**Figure 4:** Example rainfall event: daily precipitation and soil moisture response.

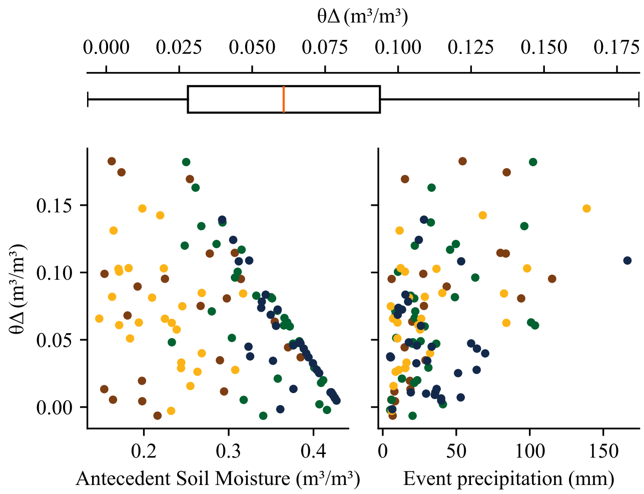


**Figure 5:** Distribution of soil moisture change ($\Delta\theta$) versus antecedent soil moisture and event precipitation.

## References


[1] P. E. O'Neill et al. *SMAP Enhanced L3 Radiometer Global and Polar Grid Daily 9 km EASE-Grid Soil Moisture, Version 6.* Subset: Baton Rouge, Louisiana, 2022–2024. Accessed 2025-09-27. Boulder, Colorado USA, 2021. DOI: 10.5067/M20OXIZHY3RJ. URL: https://nsidc.org/data/SPL3SMP_E.

[2] G. J. Huffman et al. *GPM IMERG Final Precipitation L3 1 day 0.1 degree × 0.1 degree V07 (GPM_3IMERGDF).* Subset: Baton Rouge, Louisiana, 2022–2024. Accessed 2025-09-27. Greenbelt, Maryland, USA, 2023. DOI: 10.5067/GPM/IMERGDF/DAY/07. URL: https://data.nasa.gov/dataset/gpm-imerg-final-precipitation-l3-1-day-0-1-degree-x-0-1-degree-v07-gpm-3imergdf-at-ges-dis-13ed8.

[3] Mohamed Boujoudar et al. *Modeling Water, Heat, and Nitrate Dynamics in the VadoseZone: A Case Study of the Beauce Aquifer (Orleans, France).* Tech. rep. Copernicus Meetings, 2025.