Designing an Interactive Web-based Rainfall Analysis System

Dong Hyun Jeong*, Pradeep Behera†, Bryan Higgs†, Soo-Yeon Ji§
* Dept. of Computer Science, Univ. of the District of Columbia † Dept. of Civil Engineering, Univ. of the District of Columbia
§Dept. of Computer Science, Bowie State University

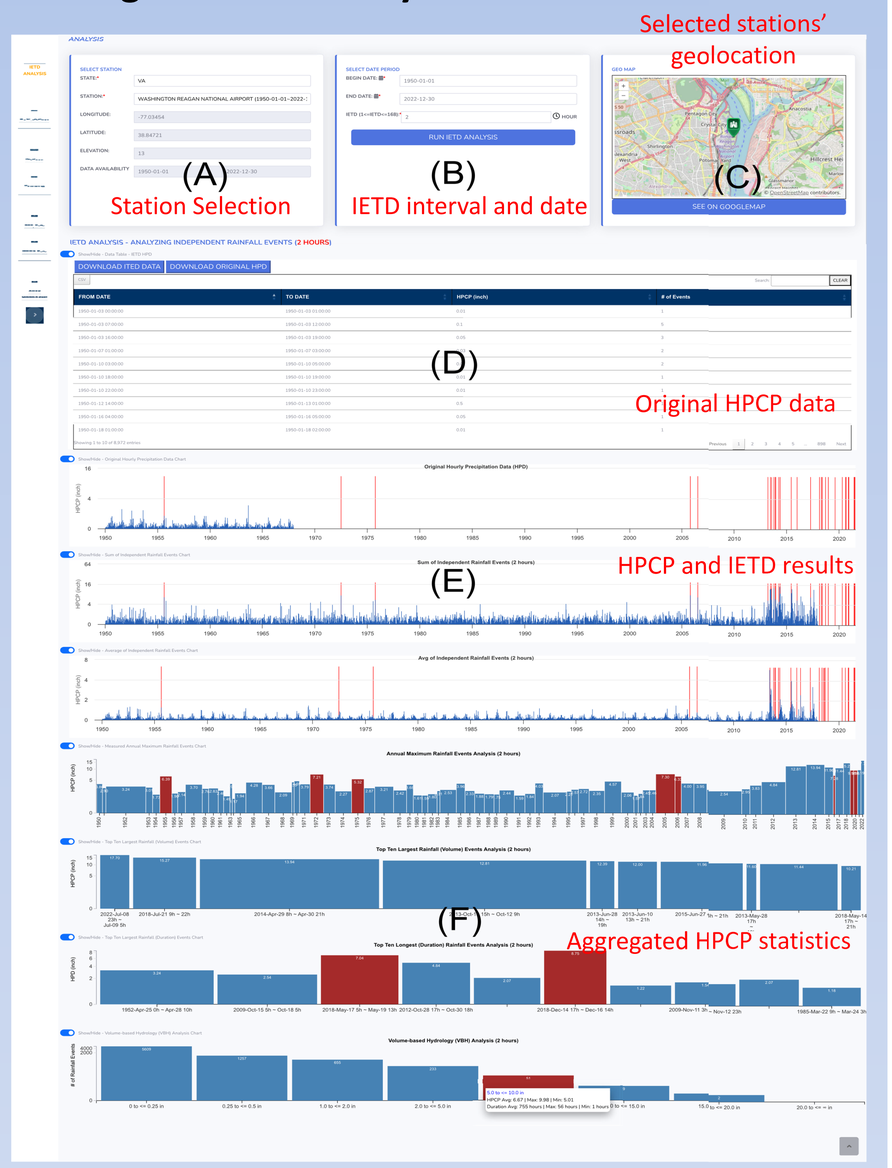
Introduction

Analyzing hourly precipitation is crucial for identifying patterns, trends, and anomalies in rainfall, which is essential for designing urban drainage systems, flood forecasting, hydrological modeling, and climate studies. Although conducting an analysis by identifying statistical characteristics of storm events with hourly precipitation data is critical, no effective system is available to provide a precise understanding of storm events by evaluating historical events. This study presents an interactive, web-based statistical rainfall analysis system that compiles all available hourly precipitation data across all U.S. states. It is designed as a web-based visual analytics system, utilizing multiple visualizations and user interaction techniques to facilitate comprehensive and interactive data analysis.

IETD analysis

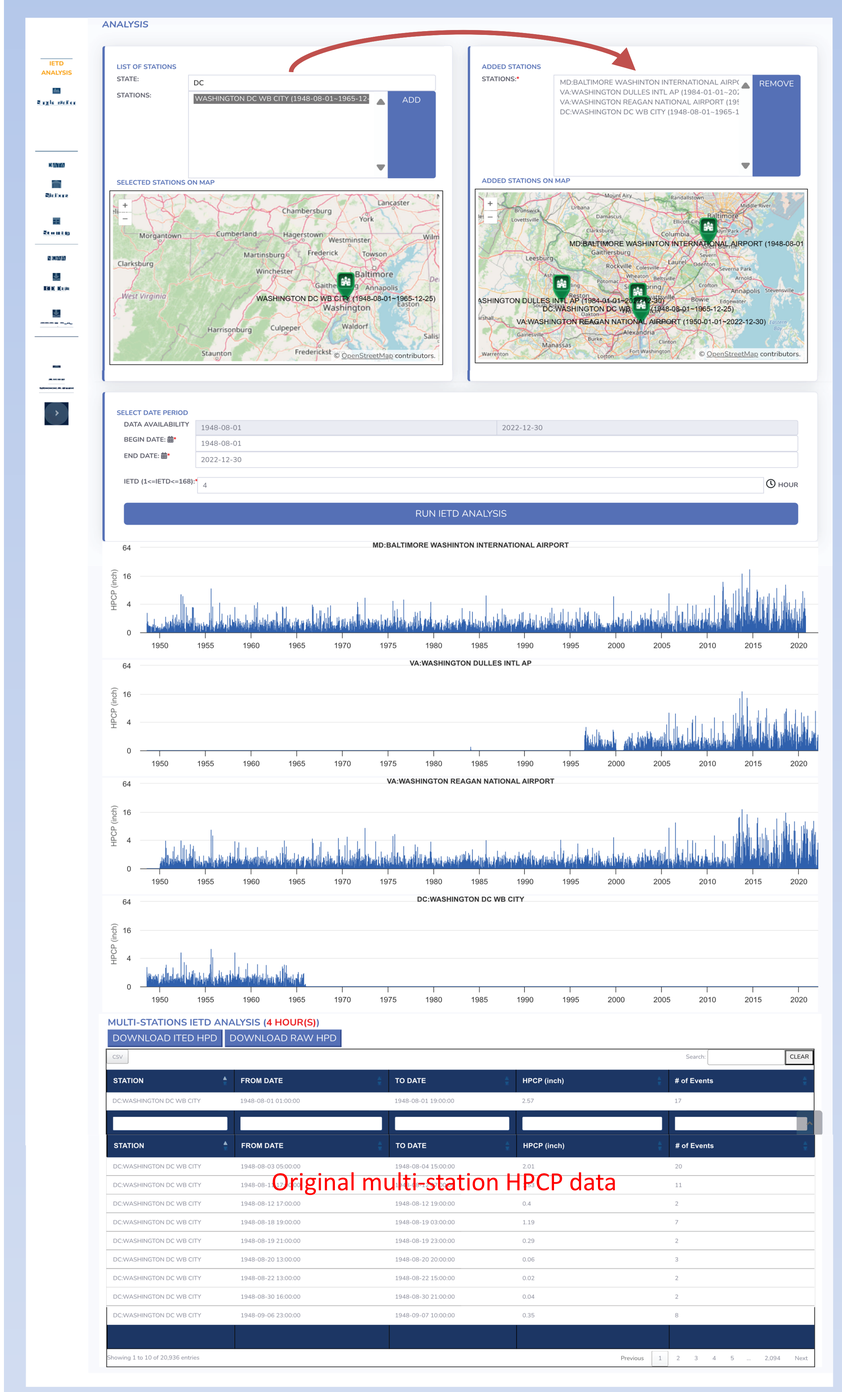
Interevent time definition (IETD) is used to analyze the statistical characteristics of storm events. IETD indicates the time period from the end of a rainfall event to the end of a direct runoff. IETD determines the time period from the end of a rainfall event to the end of a direct runoff. If the time interval between two consecutive rainfall events is greater than a pre-defined IETD value, they are considered as two separate events. The average IETD rainfall volume is measured as $\sum_{i=1}^{n} \frac{v}{n}$, where v and t indicate volume and duration, respectively. n denotes the number of rainfall events that appear in the weather station.

Single-station Analysis



To enhance interactive IETD analysis, zooming and panning techniques are integrated into all line graphs, representing HPCP and IETD results. These graphs are interconnected, ensuring that any user interaction with one is reflected to the others. For example, zooming in on the average IETD result in one graph automatically adjusts the visual representations in the remaining graphs to match the zoomed view. Users can navigate through hourly precipitation data using continuous interactions, modify date ranges, and compare IETD values across different graphs. Additionally, the system allows downloading original and analyzed data as CSV files for further exploration. User interactions are also available in all bar graphs, representing aggregated HPCP statistics. This enables users to highlight corresponding original HPCP data in associated visualizations. Hiding individual visual representations is also supported.

Multiple-station Analysis

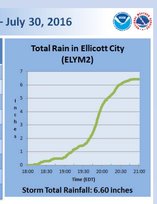


The interactive web-based rainfall analysis system supports both single-station and multi-station analysis. The single-station analysis facilitates IETD analysis on a selected weather station to conduct statistical evaluations. Conversely, the multi-station analysis enables users to perform ITED analysis across multiple chosen stations.

The illustration on the left depicts a comparative analysis of four weather stations in the vicinity of Washington, D.C. Notably, the station in Washington, D.C., stopped capturing hourly rainfall data in 1966. Meanwhile, the Washington Dulles International Airport, operational since 1962, has had HPCP data available since 1996. An assessment of the three functioning weather stations reveals an apparent increase in rainfall amounts since 2013, suggesting a trend towards more frequent high rainfall events. This trend correlates with the severe incident on July 30, 2016, in Ellicott City, MD, where over six inches of rain fell within hours, causing significant flooding that extensively damaged buildings and vehicles.

Historic Rainfall in Ellicott City, Maryland – July 30, 2016

Duration	Max Rainfall in Duration	Time of Occurrence
1 minute	0.20"	7:52pm-7:53pm
5 minutes	0.80"	7:50pm-7:55pm
10 minutes	1.44"	7:50pm-8:00pm
15 minutes	2.04"	7:46pm-8:01pm
20 minutes	2.44"	7:44pm-8:04pm
30 minutes	3.20"	7:36pm-8:06pm
60 minutes	4.56"	7:30pm-8:30pm
90 minutes	5.48"	7:00pm-8:30pm
2 hours	5.96"	6:50pm-8:50pm



Information obtained from the Ellicott City (ELYM2) rain gauge. This gauge reports in 0.04" increments.

(c) National Weather Service
https://www.weather.gov/lwx/EllicottCityFlood2016

Conclusion

We introduce an interactive web-based rainfall analysis system that allows users to easily perform quantitative analyses of rainfall events, focusing on identifying outliers through IETD analysis. This system enables detailed examination of the duration of significant rainfall events, which is vital for flood forecasting and water resource management. The duration of these events is critical to understanding their impact on hydrological systems. Additionally, the designed system supports volume-based hydrology analysis by quantifying the number of rainfall events according to the volume of rainfall. It concentrates on measuring, analyzing, and managing the water volume within hydrological systems and emphasizes the movement of water through these systems over time. By classifying rainfall events based on rainfall volume, the system aids in understanding the variability and distribution of rainfall, providing valuable insights into hydrological patterns.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 2107451 and 2219532.

References

[1] B. Adams and F. Papa. Urban Stormwater Management Planning with Analytical Probabilistic Models. Wiley, 2000.
[2] J. Joo, J. Lee, J. H. Kim, H. Jun, and D. Jo. Inter-event time definition setting procedure for urban drainage systems. Water, 6(1):45–58, 2014. doi: 10.3390/w6010045 1
[3] K. Kim, Y. H. Bae, and H. S. Kim. Estimating the natural disaster inter-event time definition (NIETD) to define compound natural disasters in South Korea. Natural Hazards, Apr 2024. doi: 10.1007/s11069-024-06549-6