CW3E Summer Internship Project Write-Up

Lauren Bolotin

Mentored by: Dr. Nina Oakley, Dr. Luke Odell

Introduction

Post-fire debris flows and flash floods are a growing concern in California due to changes in precipitation and fire regimes associated with climate change, and landscapes are most vulnerable during intense precipitation events occurring over burned watersheds during 1-2 years after burning when vegetation has not yet recovered and hillslopes are more susceptible to erosion (Kean and Staley 2021, Oakley 2021). While hourly observations of precipitation are widely available in California for developing precipitation intensity-duration (ID) thresholds for debris flows and for monitoring as precipitation approaches these thresholds, sub-hourly data is much less readily available. This is in spite of the fact that 15-min precipitation observations are most critical for understanding risk of post-fire debris-flow hazards (Kean et al. 2011). Our primary goal is to investigate the relationship between hourly and sub-hourly extreme (≥ 95th percentile) precipitation in California by determining how 15-min precipitation is distributed throughout hours of extreme rainfall and calculating the correlation between extreme hourly precipitation and the maximum 15-min intervals within those extreme hours. This will elucidate the value of sub-hourly observations and the information they can provide in support of decision-making related to post-fire hydrologic hazards. We use the ALERT networks (Automated Local Evaluation in Real Time; Platt and Cahail 1987) operated by various California counties and assess the utility of these networks for investigations of extreme rainfall characteristics.

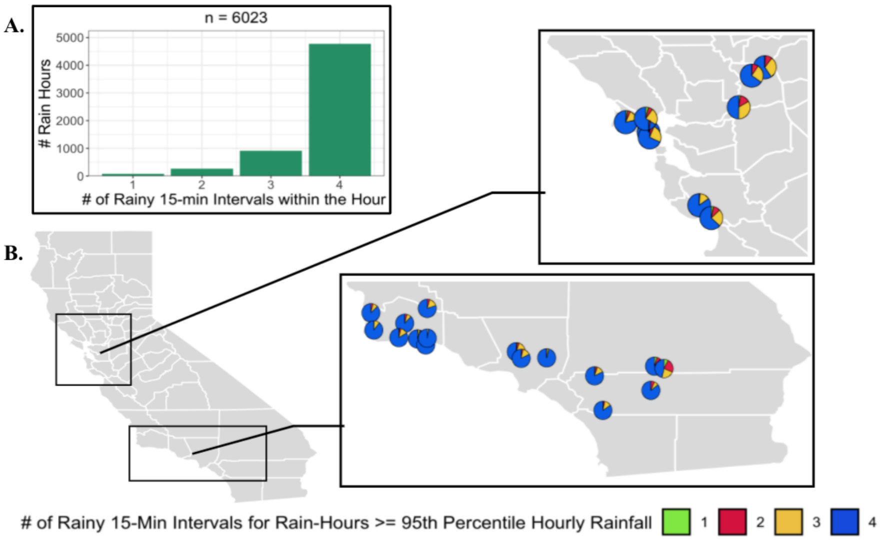

Figure 1. A) The number of rain-hours with hourly rainfall greater than or equal to 95th percentile hourly rainfall at each site with rain occurring during 1, 2, 3, or 4 15-minute intervals within the hour. B) Pie charts demonstrating the proportion of rain-hours with hourly rainfall greater than or equal to 95th percentile hourly rainfall at each site with rain occurring during 1, 2, 3, or 4 15-minute intervals within the hour.

Data

We obtained data from ALERT rain gauges in several California counties. As data had to be accessed through county staff, we were only able to obtain 2-5 stations per county. We processed the tipping-bucket rainfall ("event") observations into 15-min and hourly interval data. As our interest was focused on high intensity precipitation, to quality control the data, we flagged all hourly precipitation observations >= 1 in/h for further investigation. We obtained radar images from the National Centers for Environmental Information ((https://gis.ncdc.noaa.gov/maps/ ncei/radar) to determine whether intense precipitation was probable at the time of interest. Where radar images were ambiguous, we obtained hourly precipitation observations from nearby gauges in the RAWS network from MesoWest (https://mesowest.utah.edu/) to see if precipitation of similar magnitude was recorded in the surrounding area. Where an hourly value could not be validated by radar and/or RAWS, the hour was removed from the dataset. Stations with excessive numbers of unverifiable observations or timestamp issues suggesting compromised data quality were also removed. For parts of our analysis where we investigated all hours of rainfall, as opposed to ≥ 95th percentile rainfall, we removed hours reporting ≤ .1 inches to account for fog-drip that is not representative of the processes occurring during the more robust rainfall events we are interested in.

Methods

We explored how precipitation is distributed throughout 15-min intervals within rain-hours and extreme rain-hours both temporally and quantitatively. For each rain-hour at each station, we calculated the number of 15-min intervals that exhibited rainfall within the hour. To understand how the quantity of rainfall was distributed throughout rain-hours, we determined what fraction of the total hourly precipitation was constituted by the maximum 15-min precipitation observation within the hour. Lastly, to investigate the relationship between hourly and 15-min precipitation amounts, we plotted all extreme (≥ 95th percentile) hourly rainfall observations against the maximum 15-min rainfall observations within those hours to determine the correlation. To understand the extent to which extreme 15-min precipitation may be concealed by hourly precipitation observations, we plotted 15-min precipitation values ≥ 95th percentile at a specific rain gauge against the hourly precipitation values during which these 15-min intervals occurred. We then determined the proportion of events that would or would not be considered extreme from the hourly observation perspective. To understand how the relationship between extreme 15-min and extreme 15-min precipitation varies spatially, we calculated a parameter S to standardize data across gauges (**Fig. 3A**).

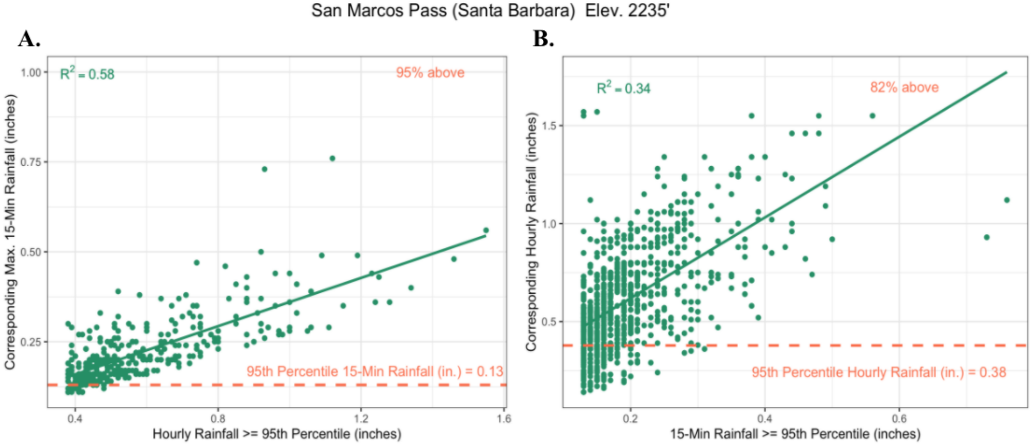

Figure 2. A) Correlation between hourly rainfall >= 95th percentile and the maximum 15-minute rainfall within those hours at San Marcos Pass in Santa Barbara County B) Correlation between 15-minute rainfall >= 95th percentile and the hourly rainfall for hours during which those 15-minute events occurred at San Marcos Pass in Santa Barbara County.

Results

For all rain-hours from all gauges, we found that the majority of rain-hours had precipitation falling during 3 or 4 of the 15-min intervals within them, and less frequently had rainfall during just 1 or 2 15-min intervals. The proportion of rain-hours with rain in 1, 2, 3, or 4 15-min intervals varied by site (**Fig. 1B**). For rain-hours with ≥ 95th percentile hourly rainfall, there was a much larger proportion of hours with rainfall occurring during all 4 15-min intervals (79%) than observed for all rain-hours (48%).

The proportion of extreme rain-hours with rain in 1, 2, 3, or 4 15-minute intervals varied by site with a similar spatial pattern to that of the analysis of all rain-hours (**Fig. 1B**). The mean proportion of the hourly precipitation constituted by the maximum 15-minute precipitation for extreme rain-hours across all gauges was 0.42 and the median was 0.38. Extreme rainfall hours generally contained at least one interval of extreme 15-min rainfall, as the two were positively correlated at all sites; however, the correlations were only moderate (**Fig. 2A)**. Extreme 15-min rainfall generally occurred during extreme hourly rainfall, though a notable proportion of extreme 15-min rainfall observations occurred during rain-hours that were not extreme hourly rainfall at their respective gauges **(Fig. 2B)**.

The relationship between hourly extreme rainfall and maximum 15-min rainfall within extreme rain-hours compared to local climatology at each site (parameter S) varied spatially **(Fig. 3B).** The mean value of S for extreme rain-hours across all gauges was 1.04 and the median was 0.98.

A.

$$S = \frac{\left[\frac{\text{Maximum 15-minute rainfall for hour } h}{\text{95th percentile 15-minute rainfall at gauge } g}\right]}{\left[\frac{\text{Hourly rainfall for hour } h}{\text{95th percentile hourly rainfall at gauge } g}\right]}$$

B.

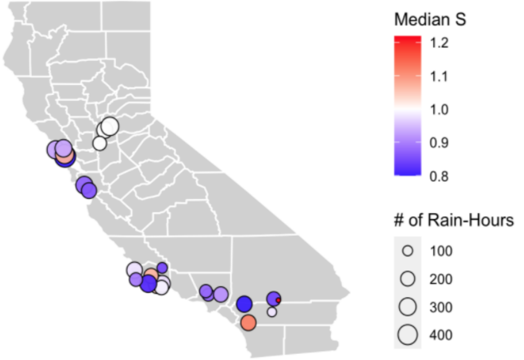

Figure 3. A) Equation for parameter S, which is a relationship between hourly precipitation and maximum 15-min precipitation, normalized for the climatology at each site B) Spatial representation of median values of S for all gauges, where the size of the points represents the number of rain-hours used to calculate the median S

Conclusion and Discussion

We found that extreme hourly and 15-min rainfall are moderately positively correlated, and that this relationship varies spatially across California. We also found that in some extreme rain-hours, all or most precipitation fell in just 1-2 15-min intervals, suggesting that hourly precipitation observations may not reliably reflect the maximum precipitation intensity occurring within extreme rain-hours; therefore, in cases where only hourly precipitation observations are available, it may be possible for decision-makers to overlook extreme rainfall at the 15-min scale because 15-min observations are not available to provide insight into the sub-hourly precipitation dynamics. ALERT data are acceptable for the purpose of monitoring extreme sub-hourly rainfall as it relates to risk of post-fire debris flows and flash floods, however challenges with data access and data quality are hurdles to be addressed. Further work is needed to understand the drivers of spatial variation in relationships between extreme hourly and sub-hourly precipitation in California. In particular, the role of elevation, topography, and the occurrence of different types of meteorological events should be investigated.

References

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